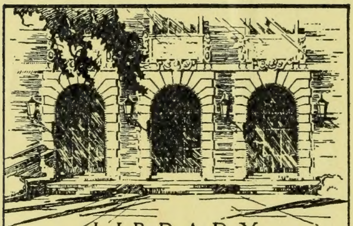

U. S. DEPARTMENT OF AGRICULTURE

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1919

PREPARED BY THE

OFFICE OF EXPERIMENT STATIONS

STATES RELATIONS SERVICE

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STATES RELATIONS SERVICE.

A. C. TRUE, Director.

OFFICE OF EXPERIMENT STATIONS.

E. W. ALLEN, Chief.

RELATIONS WITH INSTITUTIONS FOR AGRICULTURAL RESEARCH.

Supervision of Work and Expenditures of the State Experiment Stations Under Federal Appropriations.

E. W. ALLEN, E. R. FLINT, J. I. SCHULTE, W. H. EVANS, W. H. BEAL.

Experiment Station Record.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
States Relations Service,
Washington, D. C., January 20, 1921.

Sir: I have the honor to transmit herewith a report on the agricultural experiment stations in the United States for the fiscal year ended June 30, 1919. This is a part of a report prepared in accordance with the following provision of the act of Congress of March 4, 1915, entitled "An act making appropriations for the Department of Agriculture for the fiscal year ending June thirtieth, nineteen hundred and sixteen":

> That hereafter there be prepared by the Department of Agriculture an annual report on the work and expenditures of the agricultural experiment stations established under the act of Congress of March second, eighteen hundred and eighty-seven (Twenty-fourth Statutes at Large, page four hundred and forty), on the work and expenditures of the Department of Agriculture in connection therewith, and on the cooperative agricultural extension work and expenditures of the Department of Agriculture and of agricultural colleges under the act of May eighth, nineteen hundred and fourteen, entitled "An act to provide for cooperative agricultural extension work between the agricultural colleges in the several States receiving the benefits of an act of Congress approved July second, eighteen hundred and sixty-two, and of acts supplementary thereto, and the United States Department of Agriculture"; and that there be printed annually eight thousand copies of said report, of which one thousand copies shall be for the use of the Senate, two thousand copies for the use of the House of Representatives, and five thousand copies for the use of the Department of Agriculture (38 Stat. L., p. 1110.)

This report embodies the information heretofore submitted in compliance with the provisions of 34 Statutes at Large, page 64, section 5

Very respectfully,

A. C. True, *Director.*

Hon. E. T. Meredith,
Secretary of Agriculture.

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WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1919.

By E. W. Allen, E. R. Flint, and J. I. Schulte.

This report, prepared by the Office of Experiment Stations, States Relations Service, pertains to a period of readjustment which bore heavily upon the experiment stations. It affected the whole system, and because it brought to light the weakened condition of the stations and the necessity for strengthening them if they are to maintain their proper position, the situation became one of no little anxiety.

The report for 1918 dealt with the conduct of the experiment stations during the war, the part these institutions and their personnel played in war activities, and important contributions which they made to the general cause. The result was one to reflect great credit on the stations and to emphasize their importance, not alone to the agricultural industry but to the national welfare. The war inevitably interrupted the growth of the experiment stations and their work. It diverted attention and interest from them to some extent, as was natural, because the nature of their work is not spectacular and does not bring them into the public eye as does that of some other branches. The stations suffered from a combination of unusual circumstances which seriously handicapped them for the time being and reached a climax during the year. If these setbacks had been merely temporary they would not have been so serious, but the inability of the stations to recover from these handicaps and to resume their former position called attention to their real situation and the extent to which they had suffered. Numerous factors contributed to the general result and made speedy recovery most difficult.

EFFECTS OF THE WAR ON AGRICULTURAL RESEARCH.

The attention of the administrative officers of experiment stations was to an increasing extent diverted by other demands as the war progressed. Many took on engrossing special duties, several went out from the institutions altogether for a period, while others directed their attention quite largely to organizing the rapidly expanding extension work. So many emergency calls were made upon the time of these men that the station administration was reduced to a mini-

mum, and plans for the future development of its work could not receive attention. Quite naturally there was little forward-looking in that period, and there was a decrease not only of emphasis on investigation but of stimulating influence and support for it, which began to be felt by the station forces.

The situation was intensified by a large number of changes in directors. From 1914 to 1919 the directors of practically half the stations changed, in five cases twice. Eight of the former directors went into industrial positions. Furthermore, it may be noted that of the twenty-eight administrative changes which occurred, the vacancies were filled in all but three cases by persons who had not had previous experience in directing an experiment station; one-half of them were likewise new to station work, not having been connected with a station staff, and only a small part had been previously engaged in active investigation of any type.

This is a noticeable change in the system of administration during the past five or six years. Obviously it does not mark an advance in the provision of experienced leadership in the research field, and other reasons than the provision of such leadership evidently actuated the appointing powers. In part it may be ascribed to change in form of organization—a doubling up in administrative positions and duties. Thus, in nine cases the station directorship, formerly a separate office, was combined with some other office in the college, such as president, dean, or director of extension, whose exacting duties even in normal times would leave considerably less opportunity for attention to the station than formerly. In abnormal times the things which naturally suffer under pressure are those which require more intimate study and consideration, and in the case of an experiment station these are the ones on which effective supervision and advancement most largely depend. Consequently the war period brought a check to the stronger and more effective organization of these research institutions, which had seemed to be under way.

It is gratifying to note that several of the colleges have recently provided for a special officer under the dean, designated as director or vice director, to look particularly after the conduct and welfare of the stations, but the situation still leaves much to be desired in the provision for adequate administrative supervision and expert leadership.

CHANGES IN PERSONNEL.

A very serious effect on the progress of the experiment stations was exerted by change in the working forces. In addition to those who joined the war service in some form, many went into the industries or other branches more lucrative than station work. Others were unsettled by the conditions about them and the desire to render a more conspicuous service.

The loss of men was tremendous. For the six-year period from 1914 to 1919, the turnover in the personnel of the stations was no less than 80 per cent. That is to say, nearly 1,400 of those occupying technical positions, out of a total roster of approximately 1,700, left their positions for other openings, a large proportion of them outside the stations. By actual count there was a decline of about 250 persons in the combined station staffs. While the assistant grade was most largely represented in these separations, 370 department heads and leaders of special lines made a change, equivalent to an average of 7 leading workers for every station. Of this expert class, upward of 150 went into industrial or commercial lines, about 50 into extension work, an equal number to the National and State departments of agriculture, and nearly as many more into exclusively teaching positions.

While a small proportion, therefore, remained in agricultural investigation, the large majority were not only lost to the stations but to agricultural investigation as well. To this extent the stations were the poorer, because the difficulty in securing experts often led to filling the vacancies by advancement or appointment of persons less well qualified by training and experience. This difficulty in filling positions has necessitated the suspending of projects, and in some cases closing them out prematurely.

Almost everywhere there has been a decrease in the number of assistants now employed. As positions of this grade have become vacant they have often not been filled, partly because of the difficulty and partly because the funds could not be spared. In some places the only way to increase salaries and keep the work going has been through such economy. Leaders of projects have thus been required to do simple routine duties they were not accustomed to—a pathologist bugging his own potatoes, a plant breeder doing the ordinary cultural labor, a chemist making the routine determinations requiring skill but not imagination, etc. The spirit in which this has been accepted by such experts is fine, but it is false economy, and the effect on the amount and progress of research is none the less serious. It necessarily affects the character of the projects undertaken. It has been a frequent expression of men the past few years, in speaking of their future plans, to qualify by the provision that they might be able to have the needed assistance.

EFFECT ON THE WORK.

Naturally the more advanced research is the type of activity first affected by such changes in the personnel, particularly in a lowering of its grade. The effect is seen in a lower grade of inquiry, less skill and insight in devising means of advance along new lines, a performance of the simpler routine features with an omission of the

constructive inquiry essential in original research. There have been many evidences of this. The result is apparent also in the elementary character of the outlines of some of the new projects proposed for the research fund, suggesting limitation of training in the elements and the spirit of research.

The condition referred to is not isolated or highly exceptional. It is becoming so common that it raises a serious question regarding the ability of many stations to utilize any considerable additional funds in genuine research unless the staff is strengthened. This maintenance of a high-grade corps of investigators and its strengthening by the appointment of persons of advanced training is one of the most serious difficulties to be met, and the outlook in that direction is one of the gravest aspects of the situation. Apparently agricultural research as a career does not figure as prominently as it did, and the opportunities in other lines of agriculture calling for far less preparation seem more attractive to those who are coming on. The lack of special incentive to prepare for the service of the stations or any prospect of rank or salary corresponding to the high character of the work and qualifications will continue to act as a serious handicap unless it can be corrected. The standards which had come to be recognized in the past can not be lowered without distinct detriment to the character of the investigation.

EFFECT OF OTHER COLLEGE ACTIVITIES.

The return of peace brought greatly increased attendance to nearly all of the agricultural colleges, in some cases unprecedented. These students naturally had to be cared for, necessitating heavier teaching schedules and not infrequently pressing into service those assigned primarily to the stations. The time available for research by the part-time workers was materially diminished, sometimes entirely absorbed. This was a severe setback to the return of the stations to normal. It has by no means been overcome.

The practice of dividing the time of station workers with the college teaching or with the extension work is apparently on the increase. It is a result in part of straitened circumstances, the scarcity of experts, and expansion in other directions; but more often it is ascribable to the college than to the station. Pressure is laid upon the stations to carry a part of the salary of persons whose main business is teaching, and who may even be in another branch of the institution, on the assumption that they can render some service to the station. Frequently the real advantage of the arrangement lies with the college rather than the station. Where much teaching is involved, it is a source of questionable strength to the station and a tax on its slender resources. It is a reversion to a practice in which there had been marked progress in correcting.

There are indications that the attitude of some of the colleges themselves toward the advancement of research has not become increasingly favorable with the growth in other directions. Emphasis has been laid by them on certain other lines, the demands upon them have grown, and their program has continued to include more and more activities which take the college out to the people. With inadequate forces and deficient funds the result is reflected in the station, especially in the case of joint college and station employees.

These things serve to illustrate that our research is not yet on a wholly safe and secure basis. It is the first thing to be affected by an unusual condition. The teaching must go on; the extension work must not be interrupted, and there are increasing plans for outside activities. This is right and proper, but manifestly it should not be at the permanent expense of research.

With the growth of the colleges and with the dominant position they have attained, it is reasonable to expect that research should share in the general advancement when there has been time for adjustment, and that there should be active concern for its protection and stimulation—that the colleges will be insistent that their research departments grow. In the multiplicity and pressure of other interests there is some doubt whether the real condition of the stations and the consequent effects are always fully realized.

Appreciation of research is frequently of a somewhat academic or abstract character; its importance is accepted in a general way somewhat as a matter of course. As it is a mature effort and is less likely than some other branches to involve problems for the administrative head, it is easy to see that contact with the station and its needs might not always be as close as is desirable at this time. In a considerable number of cases, however, where the situation has been brought home to the authorities there has been a gratifying disposition to stress research and to make adequate support an active feature of the developmental program.

THE FINANCIAL SITUATION.

The total revenue of the experiment stations as reported for the fiscal year 1919 amounted to $7,192,912. This, compared with a total of $6,215,681 in 1918, indicates an apparent increase of nearly a million dollars. These figures, however, need to be interpreted to be properly understood, and unless such interpretation is made they are very misleading as to the support of research in the stations and the relative amount spent in its support as compared with the prewar period.

While special effort has been made in gathering the statistics of revenue, the support of the stations is so joined with other features of the colleges and their responsibilities are so diverse in many cases,

including features which have no direct relation to research, that it is very difficult to assemble figures actually representing the funds available or used for investigation and experiment.

Of the total sum reported by the stations for 1919, something over four million dollars was derived from Federal and State appropriations, while the remainder came from sales, fees, individual and community contributions, and miscellaneous sources. Though the total was nearly a million dollars larger than in 1918 and approximately two million dollars larger than in 1914, the difference is more apparent than real. The total appropriation for State stations from Federal and State sources has shown practically no increase in the six years from 1914 to 1919, inclusive. The Federal fund has remained stationary.

The State appropriation for the fiscal year 1914 aggregated $2,-575,000; it was a little less for the three succeeding years, reached $2,716,000 in 1918, and was $2,734,000 in 1919. The increase in this six-year period therefore was less than $160,000, which is quite within the fluctuations in the total State appropriation from year to year.

The record shows, therefore, that with 1914 the States ceased adding to their station appropriations in marked contrast to the practice up to that time. In each of the three five-year periods immediately preceding 1914 the total State appropriation practically doubled, or increased in an even greater ratio. Thus, it grew from $168,000 in 1894 to $240,000 in 1899, to $522,000 in 1904, to $1,035,000 in 1909, and to $2,575,000 in 1914.

The present State contribution is not to be understood as wholly direct appropriation for the station maintenance. In several instances the amount reported is an estimate of the college revenues devoted to research, or the allotment made by the college to the station as a whole. The latter is not alone for investigation, but in several instances is in consideration of special services, such as the carrying on of control work, the soil surveys, marketing enterprises, the maintenance of the college farm, or other features. The direct State appropriations also include considerable amounts of money for inspection work, and in a number of cases funds for purposes largely on the border line between station and extension work. At several institutions the facilities for instruction, so far as the farm, dairy, live stock, and orchards are concerned, are provided and maintained by the stations out of their various funds, with little aid from the colleges. These conditions in the aggregate serve to reduce considerably the total budget under this head for experimental work.

Inspection and control work of various kinds still constitutes quite a feature of the station activities and accounts for a considerable part of the direct or indirect funds included in the total of $7,000,000. As the cost of the service comes out of this revenue

these inspection fees contribute but slightly, if at all, to the net revenues for experiment and investigation, considering the stations as a whole. To an increasing extent such regulatory service is provided for in State appropriations and hence goes to swell the total from that source. Only 8 stations reported fees for such work, the total being under $400,000 and fully two-thirds of it being received by two stations.

The sales fund has quite naturally increased in recent years by reason of the high prices of products and the larger areas involved. It usually includes the revenues from substations and from farms used in experiment, together with some tracts which at present are chiefly commercial. In the case of 16 stations, the amount reported covers the entire college farm rather than the portion or features devoted to investigation; and in several other instances it includes the revenues from farms which have been given to the institution and turned over to the station for management, largely as commercial ventures at present.

The growth of the sales fund has been quite steady for many years. In the fiscal year 1894 the amount returned from this source was only $47,300; by 1900 it had nearly doubled, and in 1906, when the Adams fund came, it was over $135,000. From that time it increased rapidly, doubling in the next four years, amounting to $307,000 in 1914, to a half million in 1915–16, and close to $700,000 in 1917. In 1918 it was over $900,000, and in 1919 upwards of $1,400,000. In several cases the amount is very large, ranging from $50,000 to $180,000 or over; in one case it is given as nearly $186,000.

With the possible exception of the last two or three years, the increasing size of the return from sales implies a larger scale of operations involving land, live stock, and farm products. Incidentally it serves effectually to acquit the stations of any possible charge that they are conducting their work increasingly on a laboratory scale, showing that on the contrary they are operating under conditions which very largely conform to those of practice. Nevertheless it is quite misleading as a source of net revenue for research.

The figures reported are for gross returns, and to a very large extent they represent merely a turnover and hence are not to be counted as additional revenue. Farms conducted for experiment or for instruction or demonstration are not ordinarily expected to be revenue producers, owing to the conditions under which they must be maintained.

It is evident therefore that this large item, representing approximately 20 per cent of the total station income, is only to a very slight extent to be regarded as a source of added revenue, the responsibility and time involved in the management of extensive enterprises to a great degree offsetting any net profit. It is true that the conduct of

these larger operations frequently places better facilities at the disposal of the stations, and enables them to carry out their practical experiments on a commercial scale. This advantage and the effect on the public are not to be overlooked.

Another large item of the revenues as reported falls under the head of "miscellaneous," amounting to approximately $1,159,000. This is a convenient repository for items not easily classified elsewhere, consisting in part of allotments or estimated expenditures of the colleges for station enterprises, and the Federal appropriations for the insular stations amounting to $190,000. It is found on investigation to include also balances brought forward from the previous year, aggregating nearly $700,000. These balances are due largely to differences in the fiscal year, the maintenance of a circulating or operating fund, and the like. They were of course included in the returns for the preceding year, and they are found to be almost exactly offset by unexpended balances at the close of 1919. Hence they are not to be counted in the year's revenue. Correcting this miscellaneous item for the balances and the insular station funds leaves less than $270,000 of it to be counted in the assets of the State stations for the year in question.

All things considered, therefore, the station revenues available for the administration and support of experiment and investigation in a fairly strict sense may be said to be limited practically to the Federal and State appropriations, and to less than $270,000 derived from miscellaneous sources. There may be occasional residues under other heads, but these can not safely be counted on as net revenues. The total of $7,000,000 shrinks therefore to a little over $4,250,000, and there are some considerations of late which tend to reduce this amount in its strict application to experimental inquiry.

THE NEED FOR INCREASED FUNDS.

The revenue of the stations, as stated above, has shown practically no increase since 1914, up to which time it was growing steadily. The research activities of the stations practically ceased increasing with the close of that fiscal year, and remained unchanged during the five years following. This is the more marked since in each of the three 5-year periods immediately preceding 1914 the total appropriations from the State had practically doubled or increased at an even higher ratio. The Adams fund was being added to year by year from 1906 to 1911, and between the latter date and 1914 the States kept up the increased appropriations from that source, doubling in the three years from 1911 to 1914.

It is evident, therefore, that the stations as a group came to the period of inflated prices with only a prewar revenue and with very unusual difficulties to face, not the least of which was the keen com-

petition for workers. Because the station funds were growing to a large figure, it apparently was not realized that the funds for investigation and experiment had become stationary in the face of ascending costs. Under the circumstances the stations could not even stand still; they must retrograde or retrench. This is more apparent with some than with others, and on the whole it is remarkable how well the stations have managed to overcome the effects of their straitened circumstances and keep their main lines of investigation going.

This halt in the station appropriations is not attributed to any marked change in public sentiment, and perhaps not primarily to the effects of the war itself. But new legislation diverted attention and placed new demands on the States which have doubtless had their effect. The passage of the Agricultural Extension Act in 1914 and the Vocational Education Act in 1917 called for offsets by the States which have increased from year to year. These charges have been added to by the Federal Road Act, which makes the largest demand of all. The total offset which these three acts call upon the States to contribute is a large one, amounting for the immediate future to about $50,000,000 a year. In some cases this may make it difficult to secure any considerably increased State appropriation for research in the near future.

No institution can hope at this time to maintain its position on a prewar revenue. With the increased cost of expert service, materials, labor, and everything that goes into research, it is manifestly impossible for an experiment station to do so. The price which is being paid for delay in meeting these higher costs is a heavy one, as becomes forcefully apparent when a study is made covering any considerable range of country. It is expressed in a slowing up of research, a diminished force of attack, attention to questions of smaller range or simpler character, and a falling off in publication.

THE OUTLOOK.

Reconstruction throughout the world must rest largely upon agriculture. In this the work of the experiment stations is of paramount importance. The stations must advance and grow, and unless they do inertia and retrogression will inevitably follow, with a diminishing equipment and a lower grade of investigation. The demand upon the stations is continually increasing. Changed conditions and developments in every State bring forward new problems which need to be solved through scientific investigation. The extension service now looks largely to this source for new information, and the farmers are seeking its advice and help more extensively.

Already the legislatures of several States have made noteworthy additions to the appropriations for support. Where the stations have had opportunity to go before the people of their States the

response has usually been excellent. Three States in the South which had not previously contributed to the support of the central stations have made generous initial appropriations, and in another State the representatives of the various agricultural interests were called together, with the assistance of the president of the university, and not only indorsed a biennial station budget for nearly $170,000, but formed a committee to press it actively before the coming legislature. Elsewhere plans for seeking larger State contributions are being laid and the feeling is generally optimistic. In cases where, for local reasons, the station does not have a separate budget or is not named in the estimates, and where it is not permitted to solicit public support for larger funds—and there are some such—relief will depend upon sympathetic and appreciative action by the college administration.

There is still need for a quickening of interest in agricultural research, led by the colleges and expressed in their plans. It is important that attention be given to publicity which will bring the stations and their requirements more definitely home to the public. In a considerable proportion of the States their condition is critical. The inequalities are one of the serious features of the situation at present. Some of the stations in position to do exceptional work are suffering most from shortage of funds. As a group they have reached the limit of their ability to maintain a satisfactory output and to keep step with the advance in the demands for teaching and extension.

The situation is not one for pessimism or discouragement, but rather for right understanding and for action. Never before has there been such a great body of sound public sentiment to support the growth of agricultural institutions, and this sentiment is rapidly growing in force and in understanding. Rightly informed and guided it will enable the present situation to be relieved and will restore the station system to a position for continued growth.

INVESTIGATIONS UNDER THE HATCH AND ADAMS FUNDS.

The Federal sources of support for the experiment stations known as the Hatch and Adams funds have tended to become quite clearly differentiated in their application in the course of time. The wording of the acts indicates the limitations of their purposes, the Hatch Act reading "to aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture and to promote scientific investigation and experiment respecting the principles and applications of agricultural science," while the Adams Act states that the funds appropriated are "to be applied only to paying the necessary expenses of conducting original researches or experiments bearing directly on the agricultural

industries of the United States, having due regard to the varying conditions and needs of the respective States or Territories."

The Federal Department's interpretation of the use to which these funds may be put, having in mind the clear intention of Congress when the respective acts were passed, is embodied in the clause "original research" of the Adams Act, as distinguished from the broader provisions of the Hatch Act for "acquiring and diffusing * * * useful and practical information," through "scientific investigation and experiments." In other words, the later act attempted to reinforce the one passed nearly 20 years earlier by enlarging the amount of original inquiry along the fundamental lines of research, since experience had shown this to be essential to progress. The demands on the stations under the Hatch Act had been so heavy for strictly practical information and they had been called on for such a variety of popular activity that the attention they could give to thoroughgoing research was often very limited. Furthermore, research was not popular, because the need for it was not understood, and there was no extension service to make the contact with the farmer and supply his need for general information. The Adams Act aimed to relieve and sustain the stations, not only financially but in furthering their research; and to insure this it restricted the use of its funds and made them available gradually.

Such limitation is less necessary at the present time than when the Adams Act was passed, and the amount of original investigation and inquiry conducted under the other funds of the stations has vastly increased. There can be no doubt that the rather rigid interpretation of that act has greatly stimulated fundamental research in agriculture by directing attention to its qualities and requirements, encouraging students to prepare themselves adequately for it, and attracting to that field persons with taste and qualifications for it. Its influence on the personnel of the stations has been very marked, and the type of work it represents has been found both practical and necessary to intelligent advancement of the industry.

To properly discharge its function, an experiment station must of necessity carry on work of various grades and kinds, some of which will be relatively simple in method, aiming only at empirical results to answer local questions, or merely comparative or commercial, to meet the immediate need for advice. Such work has served a useful purpose and not all topics which arise call of necessity for thoroughgoing research at present. It is a question of the wise use of funds and facilities, having regard for what is of local importance. The station aims to advance the agricultural interests of its State, without implying the construction too narrowly, and hence it must be governed considerably by the kind of work that is needed. It can not wisely leave its results in the purely research or theoretical stage,

and it often needs to adapt to local conditions facts and theories which are not new or original with the station. But it must advance knowledge and understanding, and it must itself grow through its own efforts.

Although in selecting the lines of effort the stations are to have "due regard to the varying conditions and needs of the respective States," no station can afford to be held down by a local condition for which the extension service may be the real remedy. It must be in contact with the conditions and the needs of its State and it can not close its eyes and ears to appeals for aid, but it must do its work in its own way and meet the situation as seems best in its judgment.

The list of the projects of the stations, or the subjects to which they are addressing themselves, discloses the great variety of their effort, both as to kind and as to character, covering a scope as wide as the agriculture represented by the diverse conditions of the States.

PROJECTS OF THE EXPERIMENT STATIONS.

In response to widespread interest in having a list of projects of all the experiment stations, so arranged as to show what lines of work are in progress and where, such a list was prepared and has been distributed in mimeographed form. This is the first attempt to assemble such a catalogue of station activities. The list relates to projects in operation during the fiscal year 1919. The work of assembling and classifying the titles was done by E. R. Flint, of the Office of Experiment Stations.

The list includes about 3,750 projects. Of these 546 are in progress under the Adams fund, about 3,050 under the Hatch and State funds, and about 150 in the insular stations. Only projects relating to experiment and investigation were enumerated, those relating to purely administrative, inspection, and control work being omitted.

The list served to show how comprehensive is the combined program of the stations, and indicated the relative stress which is being laid on various departments of agricultural inquiry. By far the larger number of projects relate to crop production—soils, fertilizers, field crops, and horticultural subjects. Studies of plant diseases and insect pests have from the first constituted a prominent feature of station work, and cover a wide range. Animal husbandry, dairying, and dairy farming comprise about 700 projects, and diseases of animals add 150 more, accounting together for more than one-fifth of the total. There has been a growth in fundamental inquiry regarding animal nutrition. Rural engineering and rural economics embrace only about 100 and 75 projects, respectively. In both of these divisions there is opportunity for considerable profitable development of inquiry.

One result which should follow from the distribution of this list is to make possible a closer contact between workers on related topics. It should promote the interests of cooperation by making more evident the opportunity for it and the extent to which workers are laboring independently of one another. The information given largely removes the excuse for such duplication or repetition as may be unnecessary and not justified in the present status of experimentation. Such repetition as is frequently necessary can have more definite reference to the work of others and therefore be made more specific in its purpose.

The importance of making projects definite and of limited range has frequently been urged. The list discloses a large nunber of projects of broad, general character, although as actually conducted at present the work is frequently much more specifically directed at definite points. There is little call at this stage to perpetuate broad general topics of investigation which lack clarity of aim. Such projects may well be recast to put them in more definite form and thus bring them down to date.

There are some subjects on which comparatively little original research is now in progress, as the stations fully realize, and this situation is an indication of the need for growth. The total number of projects, however, averaging nearly 65 for each institution, is manifestly more than can usually be carried to advantage. Not infrequently workers are endeavoring to conduct more projects than they can keep up with adequately and more than can be properly supported with the present funds. They have been reluctant to discontinue these, the hope being that additional support might enable their more active prosecution. The list as a whole supplies renewed evidence of the wide usefulness of the stations and the importance of their adequate support.

COOPERATION IN EXPERIMENT STATION WORK.

The advantages of cooperation among the various agencies engaged in agricultural research are, in many cases, obvious. While not all problems lend themselves to cooperative work, a large number either present so many phases, or the value of an accumulation of data under varying conditions is so great, that cooperation is of distinct advantage. In other cases, where direct cooperation does not seem advisable, coordination of investigations along the same lines in order that results may be comparable or supplementary is of benefit. One advantage of cooperation lies in the prevention of useless duplication of work and equipment, and the opportunity for more intensive application to some particular phase by each investigator. With problems that are regional in their scope each section is brought in touch not

only with the main problem, but also with its local aspects. A further distinct advantage lies in cooperative planning, in that the combined experience and the discussions and suggestions of those who are to participate tend to a more complete grasp of the questions to be investigated. One of the obstacles in organizing a cooperative undertaking is the separation of workers and the difficulty of bringing them together around a common problem and eliciting their united effort.

It is encouraging to note that the experiment stations are extending their cooperative activities, not only among themselves, but with individuals, agricultural associations, and organizations, and with the United States Department of Agriculture in the various States. Nearly all of the stations have entered into projects carried on cooperatively with the various branches of the Federal Department of Agriculture, over one hundred such projects being reported. A number of war emergency lines of work were taken up cooperatively through the National Research Council, many of which are proving of such value that they will be continued, although the emergency that suggested them no longer exists.

Such problems as the protein requirements for growing calves and the requirements of adult animals for maintenance and milk production, entered into by a number of the stations under the leadership of the Pennsylvania Institute of Animal Nutrition; the composting of raw rock phosphate in order to increase its availability; and the relation of feeding peanuts and other factors to what is classed as "soft pork," conducted by a number of the southern stations, have yielded a greater accumulation of systematic data in a much shorter period of time and under varying conditions than could otherwise have been the case.

Not only is this type of cooperative work becoming more general, but the value of cooperation between the various departments within the stations themselves is being recognized. Many projects present a number of phases, the solution of which involves different departments, and only by their cooperation is it possible to obtain comprehensive results on the whole problem.

NEW LINES OF WORK.

Among the more recent problems that are engaging the attention of the experiment stations may be mentioned the study of the vitamines, which is modifying previously held theories on nutrition and the respective values of feeds. A number of the stations have entered this new field and are obtaining results of the greatest improtance bearing on the relation of the different forms of vitamines to growth, maintenance, reproduction, and preservation of health.

The gradual encroachment on the western ranges for farming purposes, with the resulting intensive grazing of the remaining areas which is threatening to kill out the native grasses, has led a number of the western stations to make a study of methods for their conservation. Closely connected with this study is the subject of poisonous range plants, which are causing increasing losses as the formerly abundant nutritious grasses are being used up, with the result that sheep and cattle are grazing on plants that would formerly have been passed over. A number of the western stations have taken up this line of work, and many plants formerly considered harmless have been found to contain poisonous principles. Studies of methods of eradication and of range management which will tend to prevent the grazing of live stock upon these plants promise a large reduction in losses from this cause.

Among recent results of work in entomology may be mentioned the discovery that the potato leaf-hopper is responsible for a form of the disease known as "tip burn," which in some sections has caused serious losses in this crop. The demonstration of the connection of this insect with the disease makes possible the application of effective methods of control. The timely discovery of the European corn borer by the Massachusetts station has allowed active steps to be taken for control before it becomes so firmly established as to make this impossible.

The study of the relation of peanut feeding and other factors to the production of soft pork, while not a new line of inquiry, has received a new impetus through the arrangement for cooperative study by a number of the stations in the Southern States. This will have a direct influence on a large and growing industry in that section of the country.

Years of drought, with consequent failure of crops as well as of the natural grasses on the ranges of the Southwest, take a toll of live stock that frequently results in a serious menace to the industry. Experiments by the stations in that section have demonstrated that this loss can be largely averted by feeding yucca or soapweed and some of the other desert plants when properly prepared, by which means range stock can be carried over such seasons until better conditions prevail.

The sunflower as a forage crop, introduced in the Northwest through the work of the Montana and other stations, has proved to be a valuable addition to the agriculture of that section. It has been found to be suitable for both dairy and beef cattle, makes an excellent quality of silage, and produces large yields.

Breeding and selection work, both with field crops and with horticultural plants, carried on by many of the stations, is producing higher yielding and more disease-resistant strains. Encouraging re-

sults are being obtained in the production and introduction of hardy fruits for the Northwest, by the South Dakota and other stations, which are utilizing plants found in colder climates for breeding stock for this purpose.

PERSONNEL OF THE STATIONS.

The change in personnel during the year was exceptionally large, and was due to numerous causes. In many instances, men who went into war service did not return to their former positions, and new appointments were necessary. An unfortunate contributary cause lay in inability to offer adequate salaries to compete with the opportunities offered in commercial lines, research men in all branches of science being more and more in demand for technical positions. In some instances, the station resources became relatively so restricted that a cutting down of the staff was necessary. A majority of the changes occurred among the assistants and in minor positions, but they affected heads of departments sufficiently to indicate the serious condition confronting the stations with regard to the stability of their organizations. Following are some of the more important changes:

A change in directorship occurred in eight of the stations. D. W. Working was appointed director of the Arizona station in March, 1919, succeeding President R. B. von Klein Smid, who succeeded R. H. Forbes in February, 1918. H. J. Webber assumed the directorship of the California station in May, 1919. At the Georgia station H. P. Stuckey succeeded J. D. Price as director. W. M. Jardine, director of the Kansas station, was elected president of the Kansas State Agricultural College and was succeeded in the directorship of the station by F. D. Farrell. W. P. Brooks resigned as director of the Massachusetts station in October, 1918, and was succeeded by F. W. Morse as acting director, Dr. Brooks retaining his connection with the station as consulting agriculturist. E. R. Lloyd, director of the Mississippi station, resigned and was succeeded by J. R. Ricks. L. Van Es, acting director of the North Dakota station, resigned to accept a position in the Nebraska station, and was succeeded by P. F. Trowbridge, formerly of the Missouri station. E. C. Johnson was appointed director of the Washington station, to succeed I. D. Cardiff.

A. W. Morrill, consulting entomologist, and D. C. George, consulting plant pathologist, resigned from the Arizona station.

At the Arkansas station W. L. Bleecker succeeded C. L. McArthur as head of the bacteriological and pathological department and J. B. Rather was succeeded by J. W. Read as head of the department of agricultural chemistry.

At the California station, J. B. Davidson, head of the department of agricultural engineering resigned and was succeeded by L. J.

Fletcher. J. C. Whitten, formerly of the Missouri station, was appointed head of the department of pomology.

Miss E. L. Ferry, research chemist at the Connecticut State station, died in October, 1919.

D. C. Dyer resigned as chemist of the Delaware station, and was succeeded by A. C. Whittier. C. C. Wiggens was appointed research horticulturist, but resigned at the close of the year. At the Georgia station T. E. Keitt, formerly of the South Carolina station, was appointed chemist and J. A. McClintock was placed at the head of the botany and plant pathology department during the absence of B. B. Higgins.

Paul Emerson, formerly bacteriologist at the Maryland station, was appointed bacteriologist of the Idaho station and later resigned. V. H. Young was appointed head of the botany department and C. W. Hungerford in the plant pathology department. R. E. Neidig was placed in charge of the chemical department. H. P. Davis was appointed vice director and head of the dairy department. R. K. Bennett, formerly of the Kansas station, was placed in charge of the farm crops department.

Cyril C. Hopkins, vice director and head of the agronomy department of the Illinois station, was away during the year on special agricultural work in Greece. N. W. Hepburn associate in dairy manufacture, resigned.

O. E. Reed was appointed chief in dairy husbandry at the Indiana station. A number of associates were appointed, including G. H. Roberts in the veterinary department, C. M. Vestal and F. G. King in the animal husbandry department, R. H. Carr in the nutrition department, and M. W. Gardner in the botany department. The resignations included R. E. Caldwell, acting chief of the dairy husbandry department; H. M. Weeten, associate in dairy bacteriology; and H. A. Noyes, associate in horticulture.

The principal changes in the personnel of the Iowa station included the appointment of E. D. Ball as chief of the department of entomology; the resignation of W. H. Pew, chief of the animal husbandry department, who was succeeded by H. H. Kildee; and the resignation of G. M. Turpin, chief of the poultry department, who was succeeded by H. A. Bittenbender.

In addition to the change of directors at the Kansas station, C. W. McCampbell succeeded W. A. Cochel as head of the department of animal husbandry. J. B. Fitch was appointed head of the department of dairy husbandry, Theodore Macklin head of the department of agricultural economics, and R. L. Hensel head of the department of range management. E. F. Ferrin was appointed associate in animal husbandry in charge of swine investigations and F. W. Bell of horse

investigations. B. V. Severson, associate in animal breeding, died of influenza in December, 1918, at the age of 31.

P. L. Blumenthal resigned as research chemist at the Kentucky station.

A. P. Kerr was appointed chemist at the Louisiana station, in charge of the fertilizer and feeding stuffs inspection laboratory, succeeding G. D. Cain, who was appointed assistant director in charge of the North Louisiana station at Calhoun.

Changes in the Maine station included the resignation of the biologist, F. M. Surface, and the chemist, H. H. Hanson.

E. M. Pickens was appointed animal pathologist at the Maryland station.

Some of the more important changes at the Minnesota station included the appointment of William Boss as chief of the division of agricultural engineering; C. H. Eckles, of the Missouri station, as chief of the dairy department, succeeding H. H. Kildee; L. I. Knight as plant physiologist; and J. D. Black as acting chief of the agricultural economics department. F. Jager, chief of the beekeeping division, returned from leave of absence in Serbia.

H. K. Gayle resigned as head of the animal husbandry department at the Mississippi station and was succeeded by D. J. Griswold.

M. F. Miller was acting director of the Missouri station during the absence of Dean F. B. Mumford, V. R. Gardner was appointed professor of horticulture, C. R. Moulton succeeded P. F. Trowbridge as head of the department of agricultural chemistry, and A. C. Ragsdale succeded C. H. Eckles as chief of the dairy department. H. O. Allison resigned as associate in animal husbandry and L. S. Palmer as dairy chemist.

At the Montana station M. H. Swenk was appointed chairman of the department of entomology.

M. R. Miller succeeded C. A. Jacobson as chemist at the Nevada station.

B. D. Halstead, associated with the department of botany at the New Jersey station since 1889, died in August, 1918, at the age of 66. His work had dealt extensively with the breeding of plants and improvement by selection; and he had conducted studies in various branches of plant physiology.

At the North Dakota station L. Van Es, veterinarian and acting director, resigned to go to the Nebraska station, and A. F. Schalk was put in charge of the department. P. F. Trowbridge assumed his duties as director in August. W. H. Peters, of the animal husbandry department, resigned to accept a position in the Minnesota station and was succeeded as head of the department by J. H. Shepperd. R. C. Doneghue, of the agronomy department, was succeeded by H. L. Walster. C. J. T. Doryland, the soil bacteriologist, resigned.

The head of the department of animal husbandry at the Oklahoma station, J. S. Malone, resigned and the position was filled during the year by W. L. Blizzard, as acting chief.

At the Oregon station J. S. Jones was appointed head of the agricultural chemistry department to fill the vacancy caused by the resignation of H. V. Tartar. M. B. McKay was advanced from assistant to associate plant pathologist, and W. S. Brown was appointed pomologist to take the place of V. R. Gardner, resigned.

S. M. Bain, of the botany department, and W. G. Shaw, of the veterinary department, at the Tennessee station, both died during the year. Prof. Bain had been associated with the institution since 1893 and professor of botany since 1901. His death occurred in January, 1919, at the age of 50. His experimental work dealt particularly with red clover and its diseases. Dr. Shaw, who died in April, 1919, had been with the station since 1915.

At the Utah station E. B. Brossard was appointed head of the department of farm management and R. L. Hill, head of the department of human nutrition. R. J. Becraft was placed in charge of the department of range management. W. C. Carroll, head of the department of animal husbandry, who was away on war work, returned.

C. E. Wilson was appointed entomologist at the Virgin Island station.

At the West Virginia station E. L. Anthony was appointed head of the dairy department and H. A. Jones as associate horticulturist. E. W. Sheets, of the animal husbandry department, resigned.

LEGISLATION AFFECTING THE STATIONS.

In many States no legislation affecting station work was enacted during the year. Following are notes on such legislative acts as are of particular interest in this connection:

Three special appropriations were made by the Arizona Legislature, including $10,000 for citrus investigations, $10,000 for the purchase of additional land at the Yuma date orchard, and $30,000 for irrigation investigations in Cochise County.

The 1919 Arkansas Legislature passed an act permitting the trustees of the university to draw upon the appropriation made to the university under the millage tax, to the extent of $75,000, for the purchase of land, the payments to be made as follows; $25,000 to be paid out of the appropriation for the biennial period ending June 30, 1920, and $25,000 to be paid out of each of the two succeeding biennial appropriations. Under the above act the trustees purchased approximately 425 acres of desirable land lying from 1¼ to 2¼ miles north of the university campus. No appropriations were made for branch station work, consequently the work in progress there had to be abandoned.

The last California Legislature provided for uniting the various agricultural activities of the State into the "State department of agriculture," which will have charge of all agricultural police powers in the State, including the fertilizer control and insecticide act, formerly in charge of the director of the experiment station.

In Connecticut a statute provides that the State forester and the State entomologist, both members of the station staff, with the station botanist, shall be a commission to examine, and, if found competent, to license those who undertake, for pay, the care of forest, shade, and fruit trees, and to issue certificates to them. A new and more satisfactory fertilizer law was passed which increases somewhat the income of the station. An appropriation of $100,000 was made for a new laboratory on the station grounds, for the joint use of the station and the State board of health. It is the development of a policy to concentrate in one place the laboratory research required by the State. The general assembly, at the session of 1919, increased the annual appropriation to the Storrs station from $7,500 to $12,500.

The Florida State station appropriation was cut down from $28,000 for the biennium to $10,000 for the same period.

The Idaho Legislature made an appropriation, for the first time, of direct State aid for the central station of $15,000.

In Massachusetts legislation consisted principally of interpretations and rulings by State officials based on a constitutional amendment forbidding State appropriations not fully under State control, and an old statute, to which the college and station are now amenable. These included the following rulings: No salaries in excess of $1,000 per year may be increased without the consent of the governor's council; no salaries nor wages may be increased between the first of December and the first of June, which is the usual period of the annual legislative session; apparatus and equipment may be repaired or renewed from the annual maintenance appropriations, but any addition to apparatus or equipment must first be approved by the legislature as a part of the annual budget; all cash receipts, including fertilizer fees, etc., must be remitted monthly to the State treasurer and any unexpended balances revert to the State at the end of the year. The last is an opinion based on a constitutional amendment which supersedes definite statutory provisions for the use of the fertilizer and other fees. Numerous minor rulings were made which apply to the control of station funds by other officers than those of the college.

The Minnesota Legislature passed a potato seed certification law.

Funds were appropriated for a horticultural building at the New Jersey station.

In New Mexico a pure-seed law was passed, and part of the work, according to this law, is to be done by the station, such as testing the different kinds of seeds.

The State laws of New York have made salaries of station workers statutory and imposed quite rigid control over other expenditures.

The South Dakota Legislature authorized the purchase of 240 acres of land, which will add greatly to the station's facilities.

A special appropriation of $15,000 per annum for two years was made by the Texas Legislature for the establishment of a wool and mohair scouring plant.

A feeding stuffs law and a dairy code, enacted by the Washington Legislature, require that the necessary analytical work shall be done by the station chemist, who is also State chemist. Similar agricultural and vegetable seeds legislation was enacted, but no special appropriation to the station for this work was made. An act passed establishing a division of apriculture at the State college, to regulate the importation, keeping, and sale of bees, and $4,000 was appropriated for the biennium to enforce this.

In West Virginia the legislature increased the appropriation by making the $10,000 annual war emergency fund a part of the annual appropriation. An act was also passed providing for the construction of a community fruit-packing plant, to be operated by the college of agriculture; an appropriation of $25,000 was made for building this plant and an annual sum of $4,000 to be used for operating it. The 1919 legislature appropriated an additional $30,000 to be used for farm buildings on the station farms and $15,000 for farm buildings on the Reymann Memorial Farms at Wardensville. These appropriations of $70,000 did not become available until July 1, 1919.

The only important legislation affecting the Wisconsin college of agriculture and station was the appropriation of funds for the establishment of an additional branch station in Door County. This provides $5,000 from State funds to be met by $5,000 from Door County funds for the present fiscal year, and $12,000 additional from State funds for the coming year. The sum of $15,000 was also appropriated for the purchase of land for the branch station at Marshfield.

The Wyoming Legislature passed an act placing all experiment farms and stations of the State, now existing or hereafter to be established, under the supervision, management, and control of the director of the experiment station. W. L. Quayle was appointed director of experiments. The farms at present are located at Lyman, Grover, Eden, Archer, Torrington, Jireh, and Sheridan, and an act of the last legislature calls for an additional one at Gillette.

STATISTICS OF THE STATIONS.

The detailed statistics of the experiment stations by States as to organization, working force, publications, revenues, etc., are given in the tables at the end of this report.

In the work of administration and inquiry the stations employed 1,881 persons, of which 944 were also members of the teaching staff of the coleges, and 410 assisted in the various lines of extension work. During the year the stations published 1,285 annual reports, bulletins, and circulars, aggregating 25,046 pages, and these were distributed to 959,068 addresses on the regular mailing list. A revision and reclassification of the mailing lists by many of the stations reduced the number of names listed as compared with the year before.

In the statistics of revenues here presented, all balances from the previous year, heretofore given under miscellaneous, are reported in a separate column under the heading "Balances from previous year"; while the funds received from individuals and communities, accounted for separately in earlier reports, are included in the miscellaneous items. This is believed to show the financial resources of the stations to better advanatge, as it is possible, under this arrangement, to arrive at the net total revenue of the stations for the year.

The total income of the experiment stations for the fiscal year ended June 30, 1919, was $7,192,912.41, comprising $715,287.99 derived under the Hatch Act, $710,125.93 under the Adams Act, $190,000 from Federal appropriations for the insular stations, $2,734,089.20 from State appropriations, $398,795.01 from fees, $1,439,817.92 from the sale of products, $491,551.75 from miscellaneous sources, and $688,658.53 carried over as balances from the previous year.

At present, six of the stations receive no State aid, two others receive appropriations for the branch stations only, and four others receive less than $5,000. Nine stations are receiving over $100,000 each from the State, the highest being $265,500.

The estimated value of additions to the equipment of the stations during the year was as follows:

Buildings	$433, 694. 26
Library	19, 726. 59
Apparatus	63, 547. 26
Farm implements	102, 166. 30
Live stock	184, 646. 81
Miscellaneous	157, 046. 54
Total	960, 827. 76

Additions to the building and equipment were not so extensive as in some years, because of the higher cost of material and labor. Some of the more prominent additions are noted as follows:

At the Delaware station a well-equipped research laboratory was added to the horticultural department.

An irrigation system was installed on a portion of the farm at the Florida station, to be used for forage crop experiments, and plans

are being made for starting experimental work at the new citrus substation at Lake Alfred.

A service building for the poultry department of the Idaho station, to cost $1,500, is nearing completion, and a greenhouse, 75 feet in length, was completed during the year, and is used by the various departments for experimental work.

A feeding plant was erected at the Caldwell (Idaho) substation providing for 144 head of cattle and 1,000 sheep, with a reserve water-storage tank holding 9,000 gallons, at a cost of $3,500. A superintendent's house, costing $2,700, and a barn costing $1,000 were built at the high altitude station at Felt.

At the Indiana station the Pinney-Purdue farm of 400 acres was purchased for $55,000, with 67 acres additional for $8,000. Live stock and equipment to the value of $12,490 were added to the station. At the Wilson farm, a house, barn, and shed were erected at a cost of $9,250. Improvements at the Moses Fell Annex included a house, shed, and poultry house, costing $7,090, with live stock and equipment, and 79 acres of additional land obtained at a cost of $2,370. Various additions to the equipment of the central station were made, to the value of $42,600.

Two glass houses and a foreman's cottage were built at the market garden field station in Massachusetts.

The new chemical building at the Montana station was completed during the year, the construction being fireproof throughout. The station will occupy three laboratories, a storeroom and two offices, and in the basement storage rooms and grinding rooms for soil and forage.

New laboratories were equipped for the veterinary and range management departments at the Nevada station.

A new wing to the dairy barn was completed at the New Jersey station.

At the New Mexico station a drying house to be used in nutrition studies was erected during the year.

Plans for a new insectary at the New York Cornell station were completed.

An office and laboratory were erected at the North Carolina trucking branch station, and a laboratory is under construction at the tobacco branch station, costing about $2,500 each.

At the North Dakota station a recent addition to Science Hall, while not used for experiment station work, relieves congestion in the old building. Stalls, harness, and other equipment have been installed for digestion investigations.

At the Ohio station a new range of greenhouses was completed, to replace the older buildings.

An underground cold frame serving as a greenhouse for the horticultural department was added to the equipment of the Oklahoma station.

Two large warehouses at the Army camp at Las Casas, Porto Rico, were transferred from War Department to the Department of Agriculture for the use of the Porto Rico station, and have been utilized for the construction of much-needed residences, laboratories, and stables.

The South Carolina station has added over $4,000 worth of purebred breeding stock to the dairy herd. A cotton gin was installed at the Pee Dee branch station.

The newly completed agricultural building at the South Dakota station is occupied in part by the station. A farm of 240 acres was purchased, available March, 1920.

Two large barns were nearing completion at the close of the year on the Cherokee farm at the Tennessee station, and at the newly established middle Tennessee substation an administrative building, stock, horse, dairy and implement barns, and four cottages for laborers were under construction.

A special appropriation of $15,000 per annum, for two years, was made by the Texas Legislature for the establishment of a wool and mohair scouring plant. The newly completed office and laboratory building, known as the Research Administration Building, was occupied.

An appropriation of $25,000 was made by the Utah Legislature for the purchase of additional land to be used for experimental purposes and for the erection of a seed house, a greenhouse, and a new horse barn, in addition to three new buildings provided by the last legislature.

Extensive repairs were made on several of the buildings already on the grounds at the Virgin Islands station, and a number of pieces of machinery were added to the equipment.

The rebuilding of the portion of the greenhouse which was destroyed by fire at the West Virginia station, was nearly completed by the end of the year. The new agricultural building, Oglebv Hall, was completed and occupied, as were two large barns on the new live-stock farm, and $1,200 was expended on the agronomy barn in fitting it up for special work.

A donation of 50 acres of land was received by the Wyoming station, with the necessary water, which will be a desirable addition to the agronomy farm. A new hog house was completed, and a contract made for the construction of a 12 by 30 foot hollow-tile silo. A number of items of valuable laboratory equipment were received.

SOME RESULTS OF STATION WORK.

The progress made in the various lines of investigation carried on by the experiment stations has been very satisfactory, notwithstanding the adverse conditions under which the work has been done. The increased cost of material and supplies as well as the difficulty of maintaining the staff made it increasingly difficult, in many instances, to pursue successfully the program already undertaken or to institute new lines of work.

Following is a brief summary of some of the more important lines of progress during the year:

AGRICULTURAL CHEMISTRY.

The Oklahoma station finds that a portion of the prussic acid that develops in grain sorghums is given off during the process of curing, the amount depending on the length of time required for curing and the condition of the plant. If dry, hot weather occurs at this time, a greater percentage of this compound is retained.

Studies on the deterioration of stored corn and corn meal at the Kentucky station show that if corn does not contain over 12 per cent of moisture it will keep in a dry atmosphere, and meal made from such corn will remain in good condition for a year or more, but if the moisture reaches 15 per cent molds develop and the corn spoils. The factors causing deterioration are moisture, enzyms, heat, and microorganisms. Aseptically prepared samples, free from moisture, at room temperature, gave a germ count of only 15 to 30 per gram after 34 days, and 30 to 120 after 94 days, while samples with 20 per cent of moisture were overgrown with molds after 34 days and contained millions of organisms per gram after 94 days.

Chemical studies of frosted wheat at the Montana station show that the earlier this occurs the less completely the proteins are built up. Normal wheat contains from 4 to 5 per cent of nonprotein nitrogen, while in frozen samples it runs as high as 12 to 14 per cent, the frozen samples showing an increase in reducing sugars also. This difference in composition makes an appreciable difference in the baking qualities.

The baking qualities of wheat were investigated at the Washington station also, with the conclusion that "quality" does not depend on the percentage of gluten alone, various other factors entering into it, particularly the basic nitrogen. Cultivation was found to have an influence on the nitrogen content of wheat, which can be increased as much as one-third by proper methods, although this is closely connected with moisture conditions. There was not much difference in this respect between winter and spring wheat under proper handling.

At the Montana station yellowberry was found to be high in wheat cut in the milk stage, dropping to a minimum with later cuttings, and then rising again.

A study at the Minnesota station of the chemistry of disease resistance in plants has led to an interesting theory of the possibility of something corresponding to the vitamines in animal nutrition, which are necessary for plant growth, the presence or absence of which may explain immunity to certain diseases.

Investigation of the clarification processes in cane sugar at the Louisiana station shows that it is possible to get more sugar out of the molasses than by the ordinary sulphitation process, by treating raw juice directly with kieselguhr and decolorizing the filtrate with carbon.

A number of the stations, notably those in Arizona, Colorado, Nevada, and Wyoming, made extensive studies on poisonous range plants. The toxic principles of three species of larkspur have been isolated and identified. These differ with each species, some containing more than one alkaloid, mostly crystallinic. These are poisonous to cattle, but less so to sheep, and horses do not eat the plant to any extent. Other poisonous plants, such as the woody aster and the whorled milkweed, have also been studied. The Mississippi station has isolated the toxic principle of ergot on paspalum. It occurs in the oil and apparently is not an alkaloid.

The North Carolina station in extensive studies of gossypol, the poisonous principle of the cotton seed, found it to be in the resin glands distributed throughout the entire kernel, both the meat and hulls containing from 0.6 to 0.8 per cent. Feeding experiments showed that the presence of an alkali or of iron salts reduces the toxicity to some extent, as does cooking the kernels.

An investigation by the Oklahoma station of the development of oil in cotton seed shows this to be continuous and uniform. No sugar is found previous to the formation of the oil, except a little glucose, which remains quite constant during growth.

A profitable method of making acetic and lactic acids from corncobs was perfected at the Wisconsin station.

A study of the chemical changes which take place in a lime-sulphur-lead-arsenate combination spray, by the Kentucky station, showed that if acid lead arsenate is used, a portion of the sulphur reacts with the lead salt to form a sulphid and soluble salts of arsenic, decreasing the efficiency appreciably. This can be largely corrected by adding lime at the rate of 10 pounds to 100 gallons of solution.

The Wyoming station has been very successful in alkali proofing cement. Among the salts commonly present in "alkali," magnesium chlorid had the greatest disintegrating effect, because of the action of hydrochloric acid produced by the hydrolysis of the salt. The

presence of sodium carbonate in solutions of the other salts retards the disintegrating effects. Calcium sulphate had no bad effects. The mixing of cement in weak solutions of sulphuric acid, di-sodium phosphate, magnesium fluorid, and oxalic acid is of advantage and increases the alkali-resisting qualities.

BOTANY AND PLANT PHYSIOLOGY.

Studies at the Montana station on the effect of arsenic on vegetation showed a general suspension of all physiological activities, such as translocation, etc., with a reduction in growth.

Permeability by a given salt, studied with peach trees at the Delaware station, may vary with soil treatment. Potash-treated trees do not behave as do those which receive nitrogen and phosphoric acid. Sulphates do not influence permeability to any extent, chlorids exert some influence, and nitrates much more.

Investigations conducted at the New Jersey station on the salt requirements of agricultural plants show large differences in the requirements and proportions of salts at different stages of growth.

Studies on the translocation of mineral matter of plants at the Kentucky station confirmed previous observations that when the jack bean is grown in distilled water about half the mineral content of the bean remains unused in the cotyledons.

Studies at the California station show that sap concentration decreases as growth becomes rapid and that growth and high concentration are opposed to each other.

Conditions adverse to the normal growth of the tree were found by the same station to be responsible for die-back or winterkilling of walnuts, such as early fall frosts, prolonged drought during the early winter, a high water table, especially with sudden fluctuations of the same, and highly alkaline soils.

The California station found that plants grow well with very weak nutrient solutions. If the amount of nutrients is sufficient, the concentration, if not too high, is not an important factor. Excess of nutrients can be taken up by a plant, above the amount needed for optimum growth, without effect on the yield, and with little or no change in the composition of the seed.

In a study of nitrogen fixation at the New York Cornell station certain green algæ were found to have the property of fixing nitrogen in large quantities.

Studies of enzym activity of plants at the Delaware station showed that this was increased by the anions of plant food elements much more than by the cations.

Investigations on the optimum conditions of light for plant response at the Massachusetts station showed that cutting down the light intensity stimulated leaf growth up to a certain point, but blooming

and fruiting were diminished. It was also noted that when the stomata are closed from diminished light stimulus injury from fumigation is much diminished.

The carbohydrate metabolism in sweet corn has been studied at the Maryland station. The changes in the starch progress much more rapidly in early than in late corn. Fiber, protein, and fat come to an equilibrium at an early stage, after which the change is mostly in sugar and starch.

BACTERIOLOGY.

At the Idaho station a study has been made of the influence of various woods and sawdust on the biological activity of soils, which will apply to considerable areas in the State. The decomposition of sawdust was found generally to be so slow that it did not have much effect on the bacterial flora. There was no retarding of ammonification on the addition of sawdust where the moisture requirements were sufficient, but the addition of over 1.5 per cent of white pine sawdust caused a marked decline in nitrification.

Investigations at the Delaware station on the bacterial changes brought about in soils by liming and other treatments showed that nearly all soils were improved from a bacteriological standpoint by meeting the lime requirement, the usual effect being to increase the azotofiers and nitrifiers, and in some cases the actinomyces. The addition of lime and manure to some of the soils increased their bacterial flora 400 per cent. Manure increased the ammonifiers, especially the subtilis group, and if added without lime tended to increase the number of molds and mematodes. Phosphorus compounds alone had no influence on the flora. Fungi have been supposed to be present especially in acid soils, but the New Jersey station found this not to be the case. Azotobacter was absent in unlimed but present in limed soils, the number of fungi also being larger in the latter.

At least one organism has been isolated from Kentucky soils capable of exerting a solvent action on soil silicates, but this action is not very marked on the liberation of potash. In a study of the longevity of *Bacillus radicicola* in the soil at the Missouri station it was found that drying in the sunlight or storing in the dry state for 6 to 12 months apparently had no seriously injurious effects on the inoculating power of the soil. Associative action of bacteria in soils has been under investigation at the Colorado station, but thus far, with over 500 combinations of 17 different organisms, the ammonia formation from peptone proceeded at practically the same rate with pure cultures alone as in mixtures. A study of bacterial forms found upon rock surfaces has brought out some that are possibly new species, which appear to have the power of atmospheric nitrogen fixation.

Investigation on the form of nitrogen in the nodules of legumes at the Tennessee station has been largely a study of the agencies active in breaking down the protein in the nodules, and a pure enzym has been isolated capable of doing this. Cultures of the nodule bacteria, grown in nitrogen-free culture solutions, never contained sufficient protein to give even a qualitative reaction, but a resinous substance free from nitrogen was produced which is believed to have some relation to the growth of the plant. No amino acids were produced in the cultures and the accumulation of nitrogen in them was not definitely demonstrated. Experiments carried on at the Wisconsin station indicate that soy bean nodule bacteria are capable of living under field conditions for at least 17 years, and that they will tolerate soils having a strong acid reaction.

Studies at the New York State station on the decomposition of manure indicate that spore-forming organisms do not play an important part in this process. The most active organisms of manure are also found in the soil.

The New Jersey station has found a number of organisms, including species of Fusarium and a number of bacteria, that will oxidize sulphur.

The South Carolina station is making a study of the bacterial content of milk from milking to cooling. Holsteins showed a uniformly lower count, but the percentage increase in bacterial content was the same for both Helsteins and Jerseys. Care of the utensils used was found the main factor in producing milk low in bacterial content and in holding it sweet for the longest period of time. A rapid method for the bacteriological examination of milk by direct microscopical examination has been devised by the New York State station, which is sufficiently accurate to grade commercial milk as good medium, or poor, and which has been adopted in many localities.

Media based on liver and spleen tissue were found, by the Colorado station to be far superior to any other for the cultivation of *Bacillus abortus*.

A study of the deterioration of cane sugar at the Louisiana station has shown that mold spores contain enzyms and have the power of inverting manufactured cane sugar. A decrease in concentration of the sugar solution in the films surrounding sugar crystals, as well as an increase in the number of mold spores present, is responsible for an increase in deterioration. The mold causing most of the deterioration was *Aspergillus sydowi*. The practical control of deterioration depends upon the proper drying of the sugar under sanitary conditions which prevent mold infection.

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GENETICS.

Extensive studies carried on by the Alabama station on the inheritance of oil and protein in cotton seed and the correlation of these with other characters showed that there is a much more definite correlation of characters in the "lint index" or quantity of fiber in a unit weight of seed than in percentages. A high and a low lint index were found to be associated respectively with a small and a large amount of oil in 1,000 seed. In the relation of lint and protein also, a high lint index was associated with large amounts of protein in 1,000 seed. This was illustrated in two strains of the same variety, one with a low and one with a high lint index. The low index strain, with 6.10 per cent, required 170 bolls to give a pound of lint and 85,000 bolls to give 500 pounds of cotton. The seeds produced contained 184.5 pounds or 24.6 gallons of oil and 193 pounds of protein. With the high index strain, with 8.25 per cent, 128 bolls gave a pound of lint and 85,000 bolls gave 665 pounds of cotton. The seed contained 200 pounds or 26.7 gallons of oil and 210 pounds of protein. Thirty and five-tenths per cent more bolls must be produced by the low index cotton to equal the high index one.

Seventy-two distinct strains have been isolated from King cotton by the North Carolina station, of which 28 are still under observation in the study of plant characters. The range in these strains is considerable, the lowest averaging only 74.6 grams of seed cotton per plant, as against 183.6 grams for the highest yielding strain. In weight of bolls there was a range from 4.55 grams to 7.25 grams in length of lint from 21 to 28 millimeters and in per cent of lint from 35.3 to 42.1.

Inheritance in cereals, especially resistance to smut in wheat and oats, has been studied at the Washington station. In wheat this was found to be inheritable but complex in its segregation and not a unit character, involving at least three factors, which differ somewhat in different varieties, some of which will transmit it, others not. Crimean and Australian wheats resisted smut infection for two generations. Oats were found to act quite differently from wheat, the first generation from parents with 55 per cent of immunity showing complete immunity. Studies in the correlation of long-headed plants to yield in wheat at the South Dakota station showed some increase the first year which fell off rapidly in succeeding crops, indicating that if any benefit is to be expected from such selection it must be done yearly. From a series of studies on the correlation of characters in inheritance in oats at the Montana station correlation coefficients have been worked out for many characters that appear to be quite definite and of general application. Investigations on wheat at the North Dakota station indicate a definite segregation relative to inheritance of susceptibility to rust, but this is not conditioned by

simple ratios. Much sterility results from crossing different subspecies of wheat.

Studies in plant breeding at the Connecticut State station led to the conclusion that the physiological stimulation resulting from crossbreeding and the loss of this following inbreeding allow of a strictly Mendelian interpretation, and that good or bad results from inbreeding depend solely on the constitution of the organisms before inbreeding is commenced. As a means of analyzing and purifying a crossbred stock by the elimination of undesirable qualities, inbreeding is of the first importance in plant and animal improvement. In work with corn, vigor and productivity were reduced by inbreeding, but when lines were once established vigor was regained as a result of cross-fertilization. By following this method, high and low protein strains were developed with extremes of 17 and 6 per cent, respectively.

From crosses of a white sweet with a yellow dent corn at the Washington station a yellow sweet variety was obtained with a 5 per cent increase in sugar content. Extensive plant breeding experiments at the New York Cornell station have resulted in the development of several improved and desirable strains of field and cereal crops. Some success has been attained in combining resistance to more than one disease in the same strain, and a strain of field beans has been secured resistant to both rust and anthracnose.

A study of the inheritance of characters in tobacco at the California station showed that there may be obtained from hybrids derivatives that represent any combination of the characters of the original species and also derivatives that are not in evidence in either parent. After four or five generations of self-fertilization, the derivatives breed true, continuing so and behaving like pure lines thereafter.

At the Kansas station two, three, and four characters have been linked in orthoptera so that they will breed true, these linkages following Mendel's law perfectly.

In a study of the heritability of mutant characters in skunks at the Illinois station the method of transmission of a pure white fur was established. A study of syndactylism in swine showed that this and the normal hoof are an allelomorphic pair, as is also red and black coloration, but the two are independent of each other. A factor was found which dilutes red to a cream or white but has no effect on black.

The Delaware station has made extensive studies of inbreeding with cattle and pigs, from which the following conclusions are drawn: The dam's productive ability has little influence upon her daughters' ability to produce; a good sire is able to transmit either heavy milking ability or high butter fat test to his daughters; a small amount of inbreeding (under 10 per cent) appears to be associated with best production; an increased proportion of males seems to be associated

with inbreeding in cattle; in swine the certainty of pregnancy is reduced and smaller litters result from inbreeding; the mortality rate is higher in inbred pigs than in crossbred ones, and the rate of growth is greater in the latter; as in cattle, close breeding in pigs seems to increase the proportion of males and close inbreeding is followed by even more detrimental results than in cattle.

From data obtained by the Kansas station it is believed that it will be possible to establish a strain of Shorthorn cattle, of the broad, deep, thick-fleshed type, the cows of which will produce large quantities of milk. Five cows in this experiment are producing from 366 to 380 pounds of butter fat annually.

The records of a large number of twin births in cattle at the Maine station showed the sex ratio to be one of 2 bulls, two of 1 bull and 1 heifer, and one of 2 heifers. Twins were found to occur on an average once in 125 births.

SOILS.

Studies of the drift soils of the State by the Minnesota station show that while the fertility of both the younger and older drifts is naturally high, the limestone is practically gone from the older or red drift. This series is richer in phosphoric acid, organic and volatile matter, and nitrogen than the younger or gray drift.

The Ohio station finds the soils of that State generally deficient in phosphorus. The average increase in yield for 100 pounds of 14 per cent acid phosphate, used alone, was approximately 6 bushels of corn or $4\frac{1}{3}$ bushels of wheat, with sufficient increase in the hay crop following to pay for the fertilizer. When the phosphate was reinforced with nitrogen and potash the increase was much larger, although not always as profitable, at prevailing prices for the carriers of these elements. Investigations on the availability of phosphorus in the soils of the State indicate that it exists largely in an organic form, which is quite resistant to the agencies of decomposition promoted by cultivation, and that soil reaction has little or no influence on this resistance. Experiments on the effect of sulphofication and nitrification on the availability of rock phosphate showed that through the oxidation of sulphur the availability was increased to an appreciable extent in acid soils, but much less so in basic or neutral soils. Rock phosphate apparently does not support nitrification. The biological soil processes were found to increase slightly the water-soluble potash.

Mineralogical combined with chemical studies of the soils of the State by the North Carolina station have explained the fact, noted in many cases, that a soil evidently rich in plant food may not show a corresponding yield unless fertilized. With a few exceptions, phosphoric acid is low in the soils of the State.

Some interesting results have been obtained at the Tennessee station from cylinder experiments extending over a series of years with five types of soils. The cylinders were sunk in the ground, with rims 2 to 3 inches above the surface, and otherwise exposed to natural conditions. These became unproductive to the extent of complete crop failure in a few years except when limed, fertilizer and manure applications having little or no effect. The trouble is believed to lie in the increased moisture supply and excessive leachings, arising from the prevention of run-off by the raised rims, whereby the soil supply of calcium bicarbonate was reduced until it became the limiting factor. This has an important bearing on this method of soil investigation. Uncropped cylinders receiving lime as oxid, hydrate, and carbonate, mixed with the soil, showed a marked reduction in nitrogen content as compared with either untreated soils or those treated with ground limestone. The depth of cylinder has much to do with the amount of nitrogen recovered from sodium nitrate or other nitrogenous material, in the drainage water, as does the kind of soil, whether heavy or light.

Studies at the Minnesota station of the movement of moisture in soils showed that the difference in water capacity caused by manuring or cultural operations has little effect on productivity.

Soil moisture investigations at the Utah station indicated that the final equilibrum under irrigation requires a long period of time, involving a number of factors, and that capillarity is much more complex than is generally supposed. The optimum soil moisture for ammonification was found to be between 65 and 75 per cent of the water-holding capacity of the soil.

A study at the New Jersey station of the relation of the adsorbed material to nutrient soil solutions in sand, indicated that the adsorptive properties of unwashed sand are due to the finely divided colloidal or semicolloidal material, which is removed by washing. The reaction of the nutrient soil solution was not altered by contact with very fine unwashed sand. The adsorptive capacity of this material reduced the total osmotic salt concentration of the nutrient solution by 8.5 per cent, which, however, was eliminated by renewing the solution. The physiological balance of nutrient solutions in sand cultures was not altered by variations in the moisture content of the solid substrata. A good physiological salt balance and optimum total concentration of a nutrient solution is not sufficient to produce the best growth of which the solution is capable, when it is diffused as a film on the particles of the solid substratum, but an optimum degree of moisture is necessary to impart to the solution the maximum physiological value. A low degree of moisture results in low yields, low transpiration rates, and low water requirement ratios; a high degree of moisture results also in a low yield but in high

transpiration rates and water requirements; and medium degrees of moisture produce highest yields with high transpiration rates and medium water requirement.

At the Michigan station a study of the rate and extent of the solubility of soils showed that the concentration of the soil solution depends on the relative masses of the soil and water and is influenced by many factors. The amount of material that goes into solution increases as the ratio of soil to water is increased, up to about the the optimum water content, and then decreases. The concentration of the soil solution of the subsoil shows little variation.

It has been demonstrated at the New Mexico station that with suitable amounts of water alfalfa can be grown on the mesa lands of the State. Applications of 34 to 53 inches of water gave increasing yields of from 9,900 pounds to 1,360 pounds per acre. Cultivation of the soil after irrigation appeared to have no effect on the conservation of moisture on this type of soil.

A study of alkali in soils in its relation to crop production at the California station showed that applications of manure at the rate of 20 or more tons per acre prevented wholly or in part the injurious effect of alkali. Treatment with sulphuric acid is not considered practicable, for although it gives good results the first year it eventually leads to an accumulation of alkali. Nitrate of soda and other sodium salts were found to liberate calcium in a soluble form, available for plant growth and also subject to loss by leaching, heavy rains and irrigations tending to leach it below the root zone. In time the calcium is thus much reduced, with a concentration of sodium salts in the soil, which becomes greatly deflocculated; water penetrates with difficulty and aeration is retarded. Four years' results with soils cultivated but not cropped, compared with cropped soils, showed a falling off in total nitrogen at about the same rate in both cases, but the importance of a good summer fallow, properly cultivated to maintain a good surface mulch and prevent the growth of weeds, was demonstrated. It was found by the Utah station that water containing over 4,000 parts per million of alkali can not safely be used for irrigation. The small grains as a class were much more resistant to alkali than most other field crops, peas, beans, and blue grass being particularly sensitive. Nitrifying bacteria were found to be more sensitive to alkali action than ammonifiers. The compounds which are strongest in stimulating plants are also the most active in increasing the nitrogen content through bacterial action.

The Virginia station in studying the effects of green manure on the soil found that after turning under a crop a high degree of soil acidity was developed for about a month, but was not injurious where a good crop rotation was practised and lime was applied to the soil.

Leguminous cover crops turned under in a rotation gave striking increases in the yield of corn and wheat, but noticeably smaller increases where cut off for hay.

A series of experiments conducted at the South Dakota station to demonstrate the practicability of maintaining soil fertility by rotation, combined with applications of manure only, showed that this was not possible without the addition of some phosphorus for that section of the country. Where live-stock farming is not practiced the turning under of legumes can take the place of manure. Experiments on the depth of plowing showed that 6 or 7 inches was best for corn and 5 or 6 inches for wheat, the benefits derived from deep plowing not being sufficient to pay.

The Tennessee station found that applications of lime, either as oxid or hydrate, were identical in their effect. Moisture was found to be one of the major factors in the change of these compounds to the carbonate, which takes place usually in four or five days. The major portion of the carbon dioxid concerned in these changes was found to come from the atmosphere. Studies on the action of lime and magnesia salts on the soil potash indicate that these tend to depress the amount of potassium entering the free and film water of the soil, except with long-continued heavy treatments with calcium oxid, from which after two years there was some evidence of potash liberation. Magnesium compounds are even more pronounced than calcium in effecting the repressive action. Sulphates, formed by the oxidation of the sulphids in the soil, do not leach out when the lime is not carbonated.

The effect of lime in crop rotations at the Delaware station was marked, increasing the yield of hay nearly 40 per cent, but it appeared to be detrimental to soy beans. Crops fertilized with potash showed greater disease resistance. The use of different forms of lime gave but slight differences in crop production.

The Illinois station found dolomitic limestone to be as effective in correcting soil acidity as high calcium limestones, more lasting in effect, and not injuring crop yields. The total product from a one-fourth-inch screen was as effective as finer material. The average of the results of 10 fields, representative of southern Illinois, showed a threefold increase of wheat yield from the use of fertilizers applied in a profitable system of soil treatment.

Studies on soil acidity at the Rhode Island station indicate that this is to some extent dependent on the condition of the aluminum present, and that liming and phosphorus reduce acidity and give beneficial results, partly by rendering the aluminum unavailable. No harm resulted from the use of magnesium limestone for neutralizing acidity. An investigation at the Pennsylvania station of the residual effects of lime upon the soil showed more nitrogen and or-

ganic carbon in the soils treated with limestone than in those treated with burned lime. The relation of hydrogen-ion concentration to plant growth, studied at the West Virginia station, gave the maximum growth of the crops tried (which were wheat, corn, soy beans, and alfalfa, in cultural solutions) in slightly acid solutions. Reactions of P_H3 or lower were found decidedly toxic to all crops and a reaction of P_H7 was decidedly less favorable than P_H6. In all cultures the growth of the seedlings resulted in a slight change of reaction toward a neutral condition. Germinating seed was less sensitive to the reaction than the subsequent growth of the plant, there being little difference between P_H3 and P_H8. The effect of reaction on plant growth is largely the result of two factors—the effect on the plant and on the soil organisms—especially those responsible for the changes in soil nitrogen. No effect of the soil reaction was observed on the hydrogen-ion concentration of the cell sap of the plant. For red clover, the highest acidity permitting successful inoculation was found to be P_H5 and for alfalfa P_H6.

The Kentucky station studied the changes taking place in acid soils before and after adding various calcium salts, and found that two of the six soils tried did not respond to the treatment by increased yields. One year after treatment, during which the soils were exposed to the elements, no calcium was found where it had been added as carbonate or sulphate. There was a noticeable increase of compounds of calcium with humus, except in the two soils that did not respond. An examination of the soil solutions before and after treatment showed that nitrates had increased in those soils that responded; that in all the soils the addition of calcium sulphate caused large quantities of potash to become soluble; and that in some cases the solubility of the magnesium was increased. The calcium content remained nearly constant whatever the treatment; the soluble phosphorus diminished slightly under all treatments, and sulphofication occurred in the soils that responded.

Plants grown in flasks at the New York Cornell station showed nearly a complete consumption of the nitrates present in the first three weeks of plant growth, and in some instances the plants were able to mature without additional nitrogen. The evidence showed that organic matter plays an important part in the reduction of nitrates and that growing plants probably liberate organic materials that function extensively in this way. The most active reduction occurred when the plants were approaching maturity. Enzymotic action was found to be of comparatively little importance in the reduction process. With regard to the effect of cover crops on nitrate production, it was found that with plants that winter over there is a higher soil nitrate content than is the case where the plants are killed by freezing. Grass lands, however, run low in nitrates, probably

because of the greater reducing power, which may be an explanation of the injurious effect of grass sod on orchard trees.

Studies at the California station on nitrogen fixation showed in the soil under investigation a variation of 25 to 30 per cent in the carbon and nitrogen content within an area 100 feet in diameter, indicating that soil varies to such an extent that experimental treatments and checks must be repeated many times to allow for this, otherwise erroneous conclusions may be reached.

The Missouri station found that nitrate production in the soil is related to the growth of the crop. With corn, the nitrates increased to a considerable concentration until late June, when the crop made a vigorous growth and the nitrates were rapidly exhausted. Oats and wheat exhausted the nitrates most completely by June. With grass crops the nitrates increased in early spring, but were soon practically exhausted, and remained very low during the entire season. Plowing increased nitrate production, but cultivation of the surface soil reduced the nitrates in the upper layers, indicating that shallow cultivation is better than deep as far as the nitrogen feeding of the plant is concerned. The moisture and nitrate content of a soil were negatively correlated and significant reductions of nitrates followed continued rains on open soils. Nitrification and to a less extent nitrogen fixation are dependent somewhat on the moisture content, as reported by the Montana station.

The examination of a large number of soils at the Kansas station showed about 40 per cent to contain no azotobacter, with a correspondingly low nitrogen fixing power. In no case did soils with a high hydrogen-ion concentration contain these organisms, but after the addition of lime to such soils good growths of azotobacter were obtained by inoculation. The Iowa station found a wide variation in sensitiveness of soil molds to acidity and alkalinity, some growing in high acid concentrations while others showed opposite tendencies.

Observation that the addition of any considerable quantity of straw to a soil decreases the yield in the following crop led the Washington station to make a study of the effect of this material on the bacterial flora. The results indicated that with small amounts of straw, from 0.1 to 0.7 per cent, the formation of nitrates was stimulated, but when straw was added in increasing quantities above this amount there was a progressive loss in nitrate formation, although the total nitrogen remained the same. As the amount of straw increased there was an increase in the number of bacteria, which are believed to act on the nitrate nitrogen and transform it into protein nitrogen. Cellulose apparently had no inhibiting effect on the nitrifying bacteria. In pot experiments some inhibition of the growth of wheat showed with 3 per cent of straw.

An investigation of soil erosion at the Missouri station indicated that with light and well distributed rains there is always more erosion as well as greater run-off from unplowed lands, the loss increasing somewhat with the depth of plowing. Sod land was most efficient in preventing erosion and absorbed a greater percentage of the rainfall. About 60 per cent of the rainfall was absorbed on uncultivated soil, 74 per cent on plowed soil, and 87 per cent on sod land.

A study of soil toxins at the Alabama station showed that while these are widely distributed, practically all soils contain organisms that decompose them. In many cases the organism was isolated and identified. Moisture was found to be an important factor in this decomposition. Salicylic aldehyde is not readliy decomposed and is slightly toxic. The presence of manganese in a soluble form was found to be a good indication of an acid condition, but of itself is not likely to produce harmful effects unless present in very large amounts. On the addition of lime it goes largely into an insoluble form. The toxicity of certain soil extracts is apparently due more to the acidity of the solution or to the combined effect of the acid and aluminum than to manganese, if present.

FERTILIZERS.

A number of stations have been investigating the effect of composting ground rock phosphate with soil and various other materials to increase the availability of the phosphorus. At the Georgia station composts containing phosphate with cottonseed meal when first mixed rose in temperature to 136° F., with a loss of ammonia, sulphur compounds, and othe volatile constituents. By keeping the piles covered with wet bagging, the temperature was kept below 100°, with a decrease in the losses. At the Virginia station composts of rock phosphate, sulphur, soil, and manure after 24 months gave 17 per cent of the total phosphorus as water-soluble and 84 per cent citrate-soluble. Inoculation with a sulphofying organism reduced the time one-third. The best conditions for bringing about the changes were found to be initial inoculation, a high temperature, thorough aeration, and a fair moisture content. At the Texas station no increase in availability was reported, although field applications of the compost gave crop gains in some cases. The Iowa station, on the other hand, secured a rapid production of available phosphorus in the above mixtures.

Experiments at the Virginia station on the fixation of phosphoric acid in the soils, in which the water solutions of acid phosphate were treated with iron, aluminum, and calcium salts and then added to soils in which the phosphoric acid had been depleted by growing crops, showed that the phosphorus in the so-called fixed forms was available for plant growth, although the test with neutral ammonium citrate did not show in an available form. Field studies on this

subject showed that relatively the same amounts of phosphoric acid are taken up by the corn plant or fixed in the soil, whether the phosphoric acid is applied in the form of acid or rock phosphate or as basic slag. Acid phosphate showed its superiority over rock phosphate in experiments at the Pennsylvania station in all cases except in the growth of sweet clover, where the latter constantly gave greater yields.

The results of a number of years of experiments on the fertilization of citrus trees at the Florida station showed that phosphorus, applied in any form, increased growth. Eighty per cent of the phosphoric acid that has been applied has been fixed as tricalcic phosphate. Different sources of nitrogen were found to be equally satisfactory. It was found that while citrus trees can adjust themselves to adverse conditions produced by overfertilization, this has a more marked retarding effect than quantities below the optimum. Slag, unslaked lime, ground limestone, and hardwood ashes were all followed by frenching, the most injurious of these materials being ground limestone and slag, which resulted in partial defoliation. Some of the best trees were in the most acid soils.

The Florida station demonstrated also the need of available phosphoric acid and potash for the Irish potato, and that the plants show phosphorus starvation quicker than potash starvation. The results of fertilizer tests at the Louisiana station showed profitable returns in increased yields of potatoes from the application of phosphoric acid up to the rate of 72 pounds per acre.

Experiments at the Oregon station pertaining to the relation of sulphur fertilization to plant growth indicate that this element acts directly in promoting development and also stimulates the development and action of legume bacteria, thereby causing the assimilation of more nitrogen by clover. In some sections of the State it was found to be the limiting element in legume production.

The California station has investigated the nutrition of plants as affected by nitrogen and sulphur, indicating the important rôle played by the latter. Sulphate of ammonia gave a better growth of barley than nitrate of soda or dried blood, but when an equivalent amount of sulphur was applied with the latter an equally good growth was obtained. Sulphur applied without the nitrogen gave no results.

At the Washington station, where untreated alfalfa yielded $1\frac{1}{4}$ tons per acre, applications of gypsum increased this to $4\frac{3}{4}$ tons. Oats responded readily to gypsum, while wheat did not.

In a study at the Oregon station of efficiency in handling manure to prevent losses and reduce labor, the best results were obtained when the cattle were kept in covered sheds, with top coverings of straw over the ground renewed as often as necessary. This builds up about 30 inches in a year. The cows are kept clean, there are no

flies, no leaching, and no firefanging, and the manure is handled but once a year.

At the Nebraska station in none of a series of fertilizer tests with various crops did the returns pay for the cost. Fertilizing the peanut at the Florida station increased the crop only 4 bushels per acre, not enough to pay for the application.

FIELD CROPS.

Cereal breeding at the Minnesota station has resulted in several improved strains, both for disease resistance and for yield. Soil and climate were found to have more influence on the yield than size of seed. The Nebraska station has developed and distributed a strain of wheat yielding 4½ bushels per acre more than the original, and a strain of oats yielding 7 bushels more. Excellent success has attended breeding work at the Alaska station, especially with spring wheat, barley, and oats suited to the country, as well as with new varieties of hardy strawberries. A strain of Turkey Red wheat developed at the Illinois station has averaged for five years 6 bushels per acre more than the ordinary strains. The Iowa station has also been very successful in breeding and distributing improved varieties of grain, especially oats and wheat. The South Dakota station has obtained a cross between rye and wheat by pollinating the latter with the former, but not vice versa.

The Minnesota station finds that the only relation of lodging to structural characteristics of small grains is in the thickness of the sclerenchyma cell wall. Observations on the factors related to the lodging of grain at the Ohio station indicate a direct connection between fertilizer treatment, moisture content, and strength of straw.

Cropping experiments at the Idaho station show that a more profitable system than summer fallowing wheat lands can be practiced. Growing corn in the place of fallow gave an increased profit of $35 per acre over the fallow system; with potatoes there was an increase of $100, and with peas $150, for the whole three years' rotation. The Washington station found decided variations in soil moisture and nitrate content in the summer fallow plats as affected by time and method of tillage, the most favorable practice being early spring tillage followed by such subsequent working as is necessary to keep down the weeds.

At the Delaware station bearded varieties of wheat proved to be the most dependable as to yield and tillered more freely. Potash was a valuable factor in improving the quality of grain. The yields for 20 years on continuous plats of wheat at the North Dakota station averaged 17.49 bushels for the first 10 years and 13.59 bushels for the last 10. When systematic crop rotation was practiced 60 per cent more wheat per acre was produced than the average yield for the State.

Investigations on the relation of soil moisture to yield of wheat at the Colorado station show that if this crop fails to receive water in the 10 days previous to heading, the number and the filling of the heads are greatly reduced, the effects not being overcome if water is supplied later. With sufficient water at the critical stage, an excess has little effect on the yield and is largely wasted, which fact has an important application to irrigation practices.

Evidence obtained at the Washington station shows that nitrogen and not moisture is the limiting factor in wheat production, and nitrogen fertilizers used as a substitute for summer fallow gave an increased yield in all cases. The best results with spring wheat were obtained from fall applications of fertilizer, and with winter wheat from spring applications. Eleven pounds of nitrogen per acre gave an increased yield of 4.65 bushels, and 22 pounds gave 8.6 bushels. Where straw was plowed under in the spring just before seeding, it always resulted in a reduction of yield, but the detrimental effect was not so marked when it was disked in in the fall.

The Alabama station has developed several promising strains of Fulghum and Red Rust Proof oats which are being multiplied for distribution. Three superior pedigreed varieties of oats which it is anticipated will replace the many scrub varieties now planted, have been isolated at the Wisconsin station. The Texas station has developed for distribution an improved rust-proof oats, also a high-yielding feterita.

During 9 years of variety tests of cereals at the California station Mariout barley, an introduction from North Africa, has averaged 88 bushel per acre as compared with 80 bushels for the varieties commonly grown. It also shatters less, makes a lighter draft on soil moisture, and ripens earlier. A classification of American barleys at the New York Cornell station showed that of the 600 so-called varieties only about 60 should be considered as such, most of the others being synonyms.

The results of studies in breeding corn at the Nebraska station indicate that 1 year's inbreeding will reduce the yield nearly one-half, but that the original vigor returns after the first outside cross. Inbred strains that had gone down to 14 bushels per acre came back to 48 bushels in the first cross. Corn pollen was found to begin to deteriorate in 38 hours, giving very imperfect fertilization after 48 hours; and after 58 hours it had entirely lost its viability. The amount of inbreeding that takes place naturally in a cornfield was found to be very slight.

Two varieties of high-yielding corn that will germinate at a low temperature, suitable to northern conditions, have been originated at the Wisconsin station. The request for seed of these strains has been very large, including a number from foreign countries. Strains

of Rustlers White Dent corn which will mature in 100 days have been developed and distributed by the Idaho station. The Virginia station reports that when soil moisture is kept at between 60 and 80 per cent of saturation during the critical period, which with corn is in the early stage of growth, early maturing and high yields are favored. Corn breeding at the Illinois station has produced strains with an oil content five times greater in the high series than in the low, with the protein about doubled. The improved corn developed by the Virgin Islands station is now planted to the practical exclusion of all other sorts on the islands.

Surface irrigation water is found by the Texas station to be essential to the maximum development of the rice plant. Although the size of head and of the kernel is little influenced, surface irrigation increases tillering and thus produces more heads.

The introduction by the South Dakota station of proso as a food crop has been successful, 4,000 bushels having been grown in one county alone.

In breeding work with cotton at the Alabama station, only about 25 per cent of light seed was found to germinate, as compared with 100 per cent of heavy seed. A strain (No. 307–6) resistant to wilt has been developed, and sufficient seed has been distributed to plant 1,000 acres. This is to be improved in earliness and length of fiber. The results of cotton tests carried on for the past four years at the New Mexico station have aroused a great deal of interest and led to a considerable acreage being planted. The average yield of the plats at the station was 1¼ bales per acre. The Arkansas station reports that the dropping of cotton bolls may have other than bacterial causes and may occur in disease-free plants. Any mechanical injury kills the boll and causes it to drop.

Continued cropping with cotton at the Mississippi station did not show the decrease in yield that occurs with corn. Kainit used on cotton gave no increased yield, but apparently prevented or reduced attacks of rust.

A study of place variation in cotton has been carried on cooperatively by the North Carolina and Mississippi stations, from seed originating from one self-fertilized plant in North Carolina in 1914. Seed grown at the Mississippi station planted in North Carolina has consistently produced taller and earlier maturing plants, with slightly heavier bolls and a little longer staple than that locally grown. Practically all of the Sea Island cotton planted during the year in the Virgin Islands was from pedigreed seed produced at that station. This station has made good progress in cane, corn, and cotton breeding, and is testing legumes and other crops as to their adaptability to local conditions. One seedling cane, S–C 12–4, is arousing much interest among planters and is now widely grown.

The Porto Rico station has been successful in the introduction, breeding, and distribution of varieties of sugar cane immune to the so-called mottling disease that is threatening this industry on the island. Seedling cane L511 continues to give very promising results at the Louisiana station. Last season it produced 25 tons per acre, the juice containing 13.86 per cent of sucrose, or about 3 per cent more than the common varieties. At the Florida station it was found profitable to replant Japanese cane at least every five years, and preferably every three years. Both the Porto Rico station and the Virgin Islands station have introduced Napier grass, which is receiving much attention as a forage crop. This grass has also given good results in Florida, yields of over 39 tons per acre of green feed having been obtained. It must be fed when young and succulent.

Through the efforts of the Montana station sunflowers are being planted extensively in the State. They stand more frost than corn, and yield, without irrigation, 20 tons and with irrigation 30 tons of green feed per acre. The best variety is the Mammoth Russian, which should be planted as early as possible, in Montana by the first of June, in rows 36 inches apart and 4 inches apart in the rows.

As a result of experiments in growing flax for fiber at the Michigan station a considerable increase in acreage devoted to this crop is noted in the State. Similar work is being done with hemp. Largely through the efforts of the Wisconsin station that State now leads the United States in the production of hemp, much of the fiber being shipped to England. The average yield for the year was 1,100 pounds of fiber per acre, giving a return of about $100 at the prices prevailing. The problem of seed production for this crop is being worked out by the station with promise of success. The feasibility of growing fiber flax successfully, especially in the northern counties of Wisconsin, has been demonstrated.

At the Wisconsin station attention is being given to the sorghum industry, which has resulted in the development of two improved strains, improvement in the utilization of the plant by better juice extraction and ensiling the tops and leaves, and in standardizing the sirup.

At the Nebraska station experiments on the frequency of cutting alfalfa showed that both yield and vigor are reduced if it is cut before the proper stage of maturity, but if it is allowed to get too mature the yield of hay is less. The injury done by too early cutting is permanent. The highest yield at the Kansas station was obtained by cutting when the alfalfa was one-tenth to full bloom, and the lowest yields by cutting when it was either in the bud stage, which causes a rapid deterioration of the stand, or when the seed was formed.

Considerable progress has been made at the South Dakota station in improving alfalfa for hardiness and yield.

The advantage of scarifying legume seed was shown at the Wisconsin station by an increase in the germination of sweet clover seed of from 5 to 95 per cent as a result of scarifying. Crimson clover seed was improved 16 per cent, which, with seed worth 60 cents per pound, gives scarification a value of from $9 to $10 per hundredweight.

Imported French and Italian crimson clover seed was found by the Delaware station to be superior to the native-grown seed.

The annual sweet clover, introduced by the Iowa station, continues to give excellent results both in this and other countries, especially as a green-manure crop and for pasture improvement.

The acreage of soy beans seeded in Delaware has increased very rapidly during the past two years, largely as a result of the work of the station.

Selection of Japan clover for hay and for pasture purposes, which has been conducted at the Tennessee station for a number of years, has resulted in an excellent variety, yielding more than twice the quantity of dry hay produced by the next best strain and also a large quantity of seed. The pasture strains developed make an abundance of late pasturage and ripen enough seed to reseed the ground.

A study at the Tennessee station of cowpeas grown with wheat and with corn and wheat, either harvested or turned under, with and without lime, led to the conclusion that in that State at least this crop tends to loosen the soil too much and thus facilitates the loss of nitrogen. Removal of the crop resulted in a rapid decrease in soil nitrogen.

The Louisiana station is recommending corn and soy beans as the best silage combination for the State. With this mixture a silage can be made with about 4 per cent of protein.

Sheep tansy, a native wild drought-resistant plant of California, was found by that station to be an excellent pasture for sheep and also a good bee plant.

Satisfactory results have been obtained at the Utah station in commercial sugar-beet seed production, with excellent prospects of establishing a domestic beet-seed industry which will largely replace the former importation of seed from Europe. No decided advantage to sugar beets has been obtained at the New Mexico station from the use of fertilizers or manures or the use of shade. Early plantings gave a good tonnage, high in sugar and purity.

A study at the Wyoming station of the relation of number of stems to the hill to yield of potatoes indicated that three or four stems per hill were superior in total number and weight and in marketable tubers. The average weight per hill was found to increase directly as the distance apart of hills in the row increased, up to 36 inches,

but the total yield per acre and of marketable tubers was greatest with close planting, the percentage of marketable tubers, however, being lowest in those planted close together. In a comparison of large, medium, and small tubers for seed, the average weight per hill increased directly as the size of the seed piece increased, as did the total yield and yield of marketable tubers.

Experiments at the Montana station in thinning potatoes to one stem per hill showed a decrease in total yield but an improvement in the marketable yield. It is not recommended, however, except where there is a market for a fancy product. The South Carolina station has devoted considerable attention to factors influencing seed production in the potato. Much of the pollen was found to be impotent, and it is believed that this is the cause of the failure of many varieties to produce seed. Seed production of the Lookout Mountain potato depends largely on weather conditions at the time of planting, the spring-planted crop bearing little or no seed, but later plantings being usually comparatively prolific in this respect. In selecting potato seed stock at the Nebraska station, tubers from irrigated fields were found not to be as good as from nonirrigated fields.

A study at the Maryland station of the behavior of potato tubers in the ground after the vines die showed that after the tops freeze many small tubers are formed at the expense of the large ones, hence the crop should be harvested at once after a killing frost. Tubers that have been long in cold storage tend to produce "spindling sprout," which is also found to be related to the size of the seed piece. If the seed piece is less than 1½ ounces the vigor of the plant is reduced and typical spindling sprout results. Flat seed pieces gave a weaker growth than deeper sections. An accumulation of soluble carbohydrates was found in the small pieces that produced spindling sprout, indicating that such pieces had lost their synthetic power.

Potato culture experiments at the New Mexico station showed that this crop was not a dependable one at altitudes of less than 7,500 feet in the State.

Sweet-potato storage experiments at the Alabama station showed that properly cured and matured potatoes were much less injured by cold in any method of storing, while those dug after frost all rotted. If potatoes are planted, dug, and cured early they may be kept with little danger of loss.

A cross has been originated between Sumatra and Broad Leaf tobacco at the Connecticut State station that is of excellent quality, with good yields and apparently resistant to a form of root rot that has devastated fields of Havana tobacco. Investigations at the Virginia station have shown the close relation of seed bed and field diseases of tobacco, and emphasize the importance of seed-bed control.

The results secured at the Tennessee station, in keeping crops free from weeds by merely cutting them, without cultivating the soil, showed the great effect of weeds as crop reducers.

Studies on the water requirements of sweet clover at the South Dakota station showed a decrease in growth corresponding to a decrease in water content of the soil. It was noted that those plants in which water was most nearly a limiting factor suffered most from freezing. Similar studies on the corn plant at the Nebraska station showed that the amount of water used per pound of dry matter is about the same regardless of the source or kind of seed, there apparently being no greater efficiency with dry land or even special drough-resistant corn, the only difference being that the latter varieties are histologically smaller and thus have less dry matter. The rate of seeding has considerable influence on the water requirement, which is also reduced as the fertility increases, although the total amount of water required increases on account of the more vigorous plants. The main factors influencing the water requirement are climatic conditions and leaf area.

Investigations by the Idaho station on the duty of water showed that with wheat growing in pots, it required at Moscow, where the rainfall is about 20 inches with a high humidity, 252 pounds of water for each pound of dry matter, while at Idaho Falls, with a rainfal of 15 inches, about 550 pounds were required.

Studies at the Rhode Island station on the relative ability of different crops to satisfy their phosphorus requirements when that element was quite unavailable in the soil showed that while carrots secured their entire needs, turnips and cabbages were unable to grow without phosphatic applications. Beans, wheat, and oats ranked between these extremes. With limited available phosphorus, oats made a more nearly normal growth than wheat.

The Mississippi station found that the limit of the amount of green manure which will still produce an increase in the succeeding oat crop was somewhere between 40 and 60 tons of green weight, or far beyond the quantity that could be grown on the soil at any one time. Green manuring experiments extending over a period of 10 years raised the yield of corn from 35 to 75 bushels per acre by plowing under three crops of clover during this period. Kainit used on cotton gave no increased yield but apparently prevented or reduced attacks of rust.

Applications of limestone and acid phosphate in a rotation of corn, soy beans, wheat, and clover at the Kentucky station gave a net gain of $44.71 per acre for the rotation. Investigations on the occurrence and distribution of manganese in plants, at that station, in which crops of wheat, oats, barley, and rye were grown on manganese-free sand with and without the addition of manganese compounds,

showed that the growth of wheat, barley, and rye was greatly retarded by the absence of this element, but that oats was not materially affected.

HORTICULTURE.

Good progress has been made at the South Dakota station in securing hardy fruits for the Northwest, the work of the year being mainly in crossing native raspberries with species from Siberia and other northern countries. Similar work has been done with excellent results in crossing the Alaska wild strawberry on the best French varieties to improve the quality. Work in developing hardy fruits has also included apples, pears, plums, cherries, and grapes.

Hardiness is found by the Minnesota station to be a complex character, measured by the maximum injury to the tenderest tissue at any given temperature. This station also has crossed the native raspberry with strains from the far North with good results. Winterkilling investigations at the Nebraska station indicate that as a rule scion roots are much more resistant to cold than stock roots, suggesting the possibility of improving the hardiness of fruit trees by propagating in such a way that the major portion of the root system comes from the scion wood.

The Iowa station has devised a method of securing perfect rooting from the scion by girdling its union with the stock with copper wire. The stock roots begin growth and feed the scion until the wire begins to cut through the outer bark and into the cambium layer, when the accumulation of plant food above the girdle induces root production and the scion soon establishes itself on a root system of its own. Investigations at the Missouri station indicate that the condition of hardiness may be produced as effectively by withholding moisture or by decreasing the supply of available plant food as by exposure to low temperatures. Hardiness of the roots of apple seedlings is found by the Wisconsin station to be dependent to a considerable extent on moisture, those in a dry soil suffering most injury from freezing temperatures. The cambium layer is hardier than the surrounding tissues.

Extensive studies have been in progress at the Minnesota station on the fundamental reasons for the failure of the plum to fruit. Although many blossoms may be set, often all of them are lost. A large percentage of this loss was found to be due to winterkilling, especially from sudden changes in temperature which may reduce the fruiting area from a third to a half. A large percentage of the sterility is due to the abortion of the pistil from nutritional troubles, also from the breaking down of the embryo after fertilization. Nonfertilized flowers are generally lost in the "June drop." Any or all of these causes may result in a failure to set fruit. No single American plum will set fruit when it stands alone, and a mixed planting may

give either a fertile or a sterile combination. Complete ringing of mature apple trees resulted in fuller blooming and the setting of more fruit.

Good cultivation and the application of nitrate of soda gave about equally good results in the growth of young apple trees at the Virginia station. The best fruit was obtained with high cultivation. Potash and phosphoric acid used singly had little effect on weak trees, while vigorous trees responded to the treatment. At the Indiana station 11-year-old apple trees in their fifth fruiting season, growing under a system of clean cultivation with a cover crop, bore 164 pounds of fruit per tree, while trees of the same age growing in sod produced only 24 pounds. Trees growing under a system of soil management which creates a condition of subnormal nutrition and moisture supply showed a greater loss of water per unit area of leaf surface than trees well supplied. Rye has proved to be the best cover crop for orchards in the State.

Soil treatment studies in the peach orchard at the Illinois station showed a more vigorous growth of young trees under clean cultivation than with cultivation and leguminous cover crops, and both of these treatments gave better growth than cultivation, leguminous green manure, and a fall planted cover crop of rye. Excellent results have been obtained at the Oregon station from the use of sodium nitrate in the apple orchard, an application of from 3 to 7 pounds per tree according to size increasing the yield in many cases tenfold. It was found that the type of growth, whether vegetative or fruiting, was largely dependent on the relation of the carbohydrates to nitrates in the tree, the best yields being obtained where an even balance is maintained. An excess of carbohydrates results in a large number of blossoms but the setting of very little fruit. An excess of nitrates gives a large vegetative growth and also very little fruit.

Data secured at the Washington station on orchard cover crops indicate that a permament cover, such as alfalfa and clover, may be established without checking the growth and production of the trees, provided a sufficient water supply is available and fertilizers carrying a high nitrate content are added at the time of or prior to the date of seeding the cover crop. If the crop is allowed to grow to maturity, however, it depletes the soil. The addition of nitrogen to orchard soils where this was lacking at the Arkansas station increased the set of fruit in some cases over 500 per cent, but an excess of this element tended to decrease the set. A direct correlation is noted between the vigor of the tree and the setting of fruit.

Orchard management experiments at the Iowa station showed the best results from a loose clover sod. Ten years' work on this subject at the New Hampshire station resulted in no profitable

increase in yield to date from fertilization in the apple orchard, but the fertilized trees are more vigorous. Cover crops appear to have been of some benefit, and nitrification under these has doubled that under clean culture. The response to fertilizers and cover crops is becoming more evident, however, as time goes on.

The Florida station as a result of its experiments recommends clean cultivation in the citrus grove after the trees are 3 or 4 years old. The effect of limestone in producing frenching was overcome by the use of stable manure, the beneficial action depending apparently not so much on the fertilizing effect as on the introduction into the soil of the proper bacterial flora. Fruit grown with various potash rations showed no difference in chemical composition, and the general belief that this element tends to sweeten the fruit has not been borne out, moisture and temperature factors being the most important in this respect. Lack of color in citrus fruit was found to be due to climatic conditions rather than fertilization, and is also apparently closely related to the stock used, some stocks not allowing a sufficient amount of dormancy. Trifoliate stocks seem to give the greatest dormancy.

Studies in cost of production of the apple at the Minnesota station, gave the net average profit from well managed orchards at $75 per acre. In some instances the profit went as high as $200.

A large number of hybrid apples are coming into bearing at the Idaho station, giving an opportunity to study the prepotency of the parents in transmitting their characters. In a majority of the cases where Wagner was one of the parents the shape of the seedling was typically that of that variety. In the color of the fruit none of the parents seemed to show a dominant color character except the striping of the Ben Davis, which was, however, often modified. The size of the fruit varied greatly but the average was below the size of the parent varieties. The shape of the fruit nearly always suggested a combination of the parent shapes. In flavor no apparent relation could be traced. Several of the seedlings are young fruit of exceptional flavor, of good size and keeping quality, and give promise of affording a good winter sweet variety for the State.

Some varieties that were self-sterile in one locality were found by the Oregon station to be self-fertile in others, 10 or 12 miles sometimes making the difference. A change of nutrition conditions will often ameliorate this.

A study of the relation of pollination to "June drop" of apples, at the Washington station, showed that practically all fruit that dropped before attaining a diameter of three-fourths inch contained no normal seed, indicating that fertilization had not been effective. Pollination studies at the California station show that nearly all

commercial varieties are self-sterile, so that mixed plantings are essential for successful yields.

Frost studies in the apple orchard at the Utah station showed that injury does not begin until the temperature falls below 28° F., and at 22° F. all buds were killed.

The Porto Rico station has done much to encourage the growing of vanilla, which is proving profitable as an adjunct to coffee growing, the latter industry now languishing.

A survey by the California station of the irrigation waters used in citrus and walnut groves in that State showed that in many cases such water contained considerable alkali, which although it might be considered safe ordinarily, may be dangerous in an arid country owing to the gradual accumulation of alkali through evaporation with little or no leaching. Several orchards were thus severely injured.

A simple but effective apparatus for testing the mellowness of fruit has been devised by the Washington station. It measures the pressure necessary to overcome resistance to a rounded surface.

An analysis of rosetted apple twigs showed a higher ash and alkali content than the normal, but attempts to reproduce the condition by feeding potted trees on strong alkali solution have not been successful.

The Texas station has secured a raspberry-dewberry cross that is fertile, with fine large fruit and a long picking season, and promises to be a valuable addition to the fruit of the State.

A muscadine grape has been secured at the Georgia station capable of transmitting its good qualities to its offspring. This grape is being used in crossing, to develop desirable strains. Sterility in grapes is found at the Minnesota station to be due to a degeneration of the generative nucleus, while in the strawberry it is due mainly to a tendency to diœciousness with a lopping off of the secondary flowers. In many types the pollen was found to be degenerated.

Some interesting results have been obtained at the North Carolina station on the transmission of characters in hybrids of rotundifolia grapes, especially in regard to inheritance of sex, productivity, size of fruit, and disease resistance. The extent to which rotundifolia will hybridize with other species of Vitis has been determined. With the advent of prohibition, the utilization of the wine grape was an important problem at the California station. Sun-drying was found to be practicable in the warmer districts, the yields averaging 625 pounds of raisins from 1 ton of fresh grapes. Where sun-drying is not practicable evaporation may be successfully practiced.

Work in rose breeding at the South Dakota station has resulted in a number of hardy varieties. In one case the number of petals has been increased from 25 to 49.

A comparison of summer and winter pruning of fruit trees has been continued for 10 years at the Idaho station. For the first seven years there was a slight increase in favor of summer pruning. The two following years, Jonathan and Wagner still showed greater yields from summer pruning, but with Grimes and Rome winter pruning showed an increase. Summer pruning should be done after the terminal buds are set, especially in the northern part of the State. Summer pruning is beneficial in developing color of the fruit. The principal growth of the tree was found to take place before the fruit begins to grow.

At the Virginia station June pruning gave the densest trees but also resulted in a reduction of size and vigor, from which it is concluded that the late fall and winter pruning is best for that State. At the New Jersey station summer pruning did not give favorable results on the apple. Trees that were lightly pruned came into bearing earlier and bore the most fruit. Similarly, in the peach, the fruit was found to be more uniform in size and quality from winter pruning.

Pruning investigations at the California station showed that growth is not regular, but occurs in cycles not related to the fruiting period or to irrigation applications, and that pruning should be done between these cycles. The light pruning of young deciduous fruit trees, especially light heading back, produces larger, healthier, and more stocky trees than heavy heading back. The lightly pruned trees attain bearing size and age more quickly and are not injured by producing more fruit. Light pruning also gave more favorable results on old deciduous trees. The practice among growers of heading back closely has tended to retard the development of the root system and gives a thickly shaded head. Late summer pruning of peaches, plums, cherries, and a number of other fruits resulted in a marked decrease in the size and vigor of the trees.

In pruning experiments at the New York Cornell station with young trees the reducing of the leaf surface reduced both the root and top growth to about the same extent; with older trees the top was not so much affected. The application of nitrogen to young peach trees increased the top growth much more than the root growth. At the West Virginia station, light, dormant pruning gave the best growth. Summer pruning appeared to have a devitalizing effect.

The California station has reduced the time required for pickling ripe olives from 15 to 3 or 4 days by the use of heated, aerated, and circulating liquids.

In fertilizer experiments with tomatoes at the Illinois station the yield was increased approximately 130 crates per acre by the use of

manure, as compared with no treatment. Supplementing the manure with phosphorus gave a further increase of 76 crates.

Hand pollination of greenhouse tomatoes was very successful at the Oregon station. Plants which were regularly pollinated produced 80 per cent of fruitful blossoms and a yield of 8 to 9 pounds of fruit per plant, while unpollinated plants were fruitful to the extent of only 30 per cent, were from 2 to 3 weeks later in maturing, and produced only 3 to 4.5 pounds per plant.

Selection work with tomatoes at the North Dakota station has developed strains of "Earliana" that will ripen as early as July 7, and also strains that will produce over 700 bushels per acre under field conditions. The set of fruit was found to be increased in the tomato both by pruning and by mulching at the Oklahoma station.

The Pennsylvania station has done much toward improving cabbage, tomatoes, and rhubarb in the State by the development and introduction of new strains.

Cabbages stored with the roots on gave the best results at the Montana station. Cold-storage investigations for fruit at the California station indicated that a temperature of 36° F. was better than 32°, some varieties developing internal browning at the latter temperature. A high temperature, 100° or over, delays ripening of the fruit. Fruit will keep firm if left on the trees in a dry, hot year. A study of preserving fresh vegetables at the Michigan station showed that lettuce, radish, spinach, carrots, and other vegetables, can be kept in excellent condition for some time in a "moist chamber" such as a pail with a fairly tight cover.

Vegetable gardening experiments with manure and fertilizers at the New Hampshire station gave results proportioned to the amount of manure used, even when fertilizers were supplied in addition. With no manure, even a complete fertilizer gave practically no increase over no fertilizer.

At the West Virginia station the growing of mushrooms in abandoned coal mines, if they are free from overhead drip and have good drainage, has proved practicable and has commercial possibilities.

DISEASES OF PLANTS.

Investigations at the Minnesota station disclose at least 15 forms of stem rust on grains, which act quite differently on different varieties, some grains being susceptible to one strain in one locality and not in another. The injury is caused by penetration into the stem, which prevents proper transpiration and other physiological processes, eventually weakening the stem and causing it to split. At the Indiana station leaf rust of wheat was found to occur on several common grasses. The fungus appears to have several biologic strains, and the varieties of wheat vary widely in susceptibility to its attack.

The North Dakota station has found a variety of spring wheat, introduced from Russia, which is very resistent to attacks of stem rust and promises to be valuable as a basis for breeding strains resistant to this disease. Observations at the Iowa station show that rust on grain does not appear until after the spores on the barberry have matured. Wild grassses were found to be the active agents in bridging the gap between the barberry and grain, especially squirrel-tail and quack grass.

Experiments at the Idaho station show an apparent close correlation between soil moisture and stinking smut infection of wheat. Smutty wheat planted in infected soil containing under 15 per cent of moisture gave almost no smut in the resulting crop; but with over 15 per cent moisture there was a progressively larger amount of smut, up to 38 per cent moisture, which approaches saturation, when the crop was 100 per cent smutted. It is recommended that the seed be disinfected and either early or late planting practiced, eliminating summer fallow. Investigation by the Oregon station of reports that the treatment of seed wheat with formaldehyde for smut control injured germination, showed that when the solution was used in the usual strength of 1 pint to 40 gallons of water there was only slight or no injury to the germination in laboratory tests, but when planted in the soil there was at times a loss of 50 per cent. This indicates that the blotter test may be an unsafe guide. Stronger solutions than the above injured the germination considerably. Wheat smut studies at the Washington station showed that shallow planting gives less smut than deep planting, trenching less than level planting, and wide less than narrow spacing.

The Minnesota station has studied the effects of the same fungi on different crop plants. It was found that rot of tomatoes will cause a blight of wheat, and that wheat scab will cause a rot of potatoes. Rhizoctonia is sometimes parasitic on cereals.

In studies of gummosis of citrus trees at the Florida station no individual fungus has been isolated nor have inoculation experiments been successful, and it is believed that the trouble may be due to malnutrition. It may be controlled to some extent by cutting out the affected areas and painting with an antiseptic. The Alabama station finds that different species and varieties of the citrus family and its relatives differ considerably in susceptibility to citrus canker. The citrange-quot is practically immune. The character of the spot produced is found to be distinct for each species. The optimum temperature for growth was found to be from 15° to 20° and the limits from 5° to 38°. Between 15 and 30 per cent of humidity it showed a less active growth than just above or below these points, and was slow above 50 per cent.

Much attention is being given by the Florida station to a serious disease of the avocado which has made its appearance in the State. Spraying or other methods for its control have not proved very effective as yet. A new species of Botrytis was found on the castor bean, which ruined the whole crop in the State. Studies on the pineapple wilt showed that the probable means of entrance of the causal organism was injuries caused by root knot and that methods of control should be directed to this trouble.

Identification and life history studies by the Arizona station of the fungi attacking date fruits showed these to be a combination of anthracnose and rot. A Penicilium, Aspergillus, and Alternaria have been isolated, and there may be others. The Alternaria apparently causes the skin to rupture and allows other parasites to enter. The loss of fruit from this cause is very heavy when conditions are favorable, as with high precipitation. Its control would seem to depend upon getting rid of the brown spots on the petioles, which represent the wintering over of the Alternaria.

A study of the bacterial blight of Irish potatoes at the Florida station showed that this disease could be controlled to a considerable extent by spraying with a 5 : 5 : 50 Bordeaux mixture, especially in the early stages of growth. The disease caused a loss of 50 per cent in the crop in some sections. At the Montana station a number of closely related fungi were found to be responsible for wilt and dry rotting of potatoes. Planting dry-rotted tubers does not transmit the diseases. The organism causing blackleg of the potato was found not to live over in the soil, and its control rests on the use of disease-free seed. In treating seed potatoes with corrosive sublimate solution for Rhizoctonia, the Idaho station found that the strength of the solution is weakened by repeated dippings, and that it should not be used more than four or five times to get the best results. With untreated seed 50 per cent of the crop was affected.

At the Oregon station it was found that Verticillium wilt of potatoes spreads, to a considerable extent, from plant to plant in the field during the growing season. Its transmission in seed potatoes and the fact that the organism lives over winter in the soil was demonstrated, also that infected soil from a previous crop will infect clean potatoes. A study of the organisms in seed potatoes showed that *Fusarium oxysporium* is not generally so transmitted, while *Verticillium alboatrum* is to a considerable extent. *F. radicicola* is frequently present in the tubers, as are a number of miscellaneous fungi that are not serious.

Rhizoctonia was found not to be a serious factor in causing scab at the Nebraska station. The Fusarium associated with stem-end rot was found to have quite different pathological effects from the wilt Fusarium, but the temperature relations of the two were quite

imilar. The Michigan station has demonstrated that the time of reatment of seed potatoes for the control of scab can be greatly educed from that ordinarily employed, 30 minutes immersion in olutions of formalin or corrosive sublimate being sufficient to give erfect control.

Potato mosaic studies at the Maine station indicate that the disease s transmitted only by diseased tubers and by plant lice, and does not ppear to live over in the soil. The causal organism is ultramicro-copic and infectious, infected tubers transmitting it to their progeny. The incubation period was found to be from 16 to 35 days. There ppears to be a marked tendency of the seed-end cuts to develop lants with greater percentages of mosaic than the plants from stem-nd pieces. Control of plant lice by means of nicotine sulphate, ccompanied by hill selection of healthy plants, gave control of the isease. There appears to be some relationship between this disease nd leaf roll, spot necrosis, and streak. The only method of avoiding erticillium wilt was by using seed from healthy plants.

Scab and black scurf of the potato were controlled at the Iowa tation by treating the seed for 2½ minutes at 118–122° F. with a olution of formaldehyde, 2 pints of a 40 per cent solution in 30 allons of water. The Wisconsin station has found that with a soil emperature of 30° there is practically no black scurf and that ariations in soil temperature largely influence the amount of disease resent.

In a study by the Delaware station, sweet potato pox, which n some fields caused a loss as high as 90 per cent, was found to be a ypical soil disease. Heavy applications of manure, lime, phos-horus, and combinations of these had little if any beneficial effects. White potatoes planted on an infected soil were susceptible to it, and he same is probably true of beets.

The organism causing buckeye rot of tomatoes in Florida was ound by the station to be a Phytophthora, identical or very similar o one causing a number of plant diseases in tropical and subtropical egions. It occurs on the castor bean in India; on palms in Jamaica; itrus in Argentina, Cuba, and California; tomatoes in Florida, ouisiana, Texas, Central America, and Porto Rico; and peppers and oselle in Cuba. Resistance of the tomato to Fusarium wilt was ound at the Tennessee station to vary in different sections, even on he same selections, indicating the probability of a number of strains r biologic forms of the fungus which are not equally infective. Wilt resistant strains with good yields have been developed. Evi-ently there is more than one form of Fusarium disease in the State, nd apparently some relation between the tomato wilt fungi and hose causing similar diseases in some other crop plants.

Winter blight of tomatoes, under investigation at the Pennsylvania station, is found to be carried in the seed. The organism causing this trouble is widespread and does not confine its activities to the greenhouse but sometimes appears on field-grown tomatoes. There are some indications that it may attack the potato. Cultures obtained from tomato blight at the Washington station gave a Rhizoctonia instead of a Fusarium as was expected. The organism is apparently the same one that causes the Rhizoctonia disease of the potato, and tomato blight may be produced by inoculation with potato Rhizoctonia.

An investigation of the organism causing late blight of tomatoes, *Phytophthora infestans*, at the West Virginia station showed that there were two strains, one attacking the tomato and one the potato, the latter not causing serious injury to the tomato plant. Both field and greenhouse studies at the Georgia station indicate that pepper mosaic is not transmitted through the seed nor is it carried in the soil, as has been suspected. Cross inoculations of the mosaic of pokeweed to the pepper were not successful, indicating that the practice of destroying diseased pokeweed is of no value in control of the disease on peppers.

Temperature and moisture were found to be the controlling factors in Chili pepper blight at the New Mexico station. No infection appears to take place when the soil temperature is 15° C. or less, or when the soil moisture is less than 12 per cent. The organism causing the disease, a species of Fusarium, has been isolated.

A method has been worked out at the South Carolina station which gives promise of controlling angular leaf spot of cotton as well as anthracnose, and also appears to increase and hasten germination. This consists in air-drying the seed, reducing the moisture from 9 or 10 per cent to 2 or 3 per cent.

Fusarium wilt of tobacco was found by the Wisconsin station to be worse with high soil temperatures and in acid soils. The different strains of tobacco differ markedly in susceptibility to this disease. The so-called tobacco "must," a white mold occurring on fermenting tobacco, proved to be caused by a species of Oospora. Tobacco root rot was found to live over in the soil and to cause what is called "tobacco sick" soils. This has a bearing on the place of tobacco in rotations. It can safely be rotated with clover or alfalfa but should not follow cowpeas. If no host plant is present the amount of fungus in the soil gradually decreases. The Massachusetts station finds that tobacco root rot is less prevalent on acid soils, and therefore liming for this crop has an unfavorable influence. Deficiency in organic matter also tends to augment the trouble. Comparatively large applications of phosphoric acid seem to remedy the trouble.

Owing to the appearance of mosaic disease of sugar cane, which threatens to be serious, the Louisiana station is making a special study of the disease. L511 seems to be the most resistant variety grown. The station has been quite successful in developing strains of alfalfa resistant to brown rot.

A study of corn diseases at the Indiana station indicates an apparent relation between the presence of the fungus causing rot and the accumulation of certain bases, particularly iron. This accumulates in certain tissues in the nodes of the plant, accompanied by an increased peroxidase action in these tissues, causing premature death of the affected plants. Symptoms characteristic of root and stalk rotted plants are produced by injecting iron compounds into the corn plant. These symptoms resemble one another so closely and are so intimately related to the effects of drought, low fertility of soil, poor drainage, and insect and frost injuries, that their diagnosis is sometimes difficult. The greatest loss from these rots is caused by using infected seed. Corn that is planted on infected soil may become infected later in the season. The most successful control measure that has been developed is the selection of seed from healthy, vigorous plants that show no evidence of disease in germination. The black mold of ear corn is found by the Texas station to be caused by two species of Aspergillus which enter the ear in the milk stage through some insect injury, usually the corn-ear worm. It is not a storage disease and can not be transmitted to ripe corn.

The Virginia station reports that most of the marrow type and red beans are resistant to the bean rust, while most pea and white beans are susceptible, the black and brown varieties being about equally in this respect. The work on bean mosaic at the New York Cornell station has established the fact that the virus of this disease is carried through the seed. The control of bean wilt has been successfully worked out at the Oklahoma station, by keeping the seed beans for 2 or 3 years. The loss in germination is very slight up to this time, but beans should not be kept longer than 3 years.

Three species of Fusarium were found at the Texas station to cause wilt on the watermelon but not on other cucurbits or field crops. The species causing cotton wilt will produce a similar wilt in okra. The use of manure favors the introduction and spread of cucurbit wilts. Spraying does not control them very well and resistant varieties are being sought.

The fungus causing Texas root rot is found to be sterile and to be reproduced by mycelia. It has a number of hosts, including the apple, plum, pear, and grape, and carries over particularly well on the sweet potato, but has not been found on the peach or pecan or on the grains.

Spraying with Bordeaux mixture and dry dusting with Bordeaux have given excellent results in the control of celery blight at the New

York Cornell station. The Wisconsin station has been very successful in developing strains of cabbage resistant to the "yellows," and seed of these strains has been widely distributed.

The black rot of apples has been shown by studies at the Virginia station to be less prevalent on certain varieties, especially trees on Northern Spy roots, which may give a basis for its control. The Arkansas station is also studying this disease and finds it to be the same as frogeye on the leaves. Deadwood in the orchards is a source of infection and should be destroyed. Spraying helps somewhat. This disease has caused serious losses in these two States.

Spraying experiments for the control of apple blotch at the Illinois station showed that this should be done from the second to the seventh week after the petals fall and is not necessary earlier or later. The West Virginia station has shown that for the successful control of apple rust by the eradication of red cedars this must extend at least 2 miles from the orchard. Horticulturists in the State estimate that many thousands of dollars were saved in the eastern part of the State, where this recommendation was carried out. Observations indicate that infection must take place within three weeks after the leaf opens, as it becomes immune after that. Hardy trees attacked by blister canker can be saved by cutting out the infected portion and painting the wound with lead paint containing 1 ounce of bichlorid of mercury to 2 quarts of paint, as demonstrated by the Iowa station.

A series of comparative tests at the Indiana station of dusting versus spraying for the control of apple diseases showed that dusting with Bordeaux or other standard fungicides was less effective. The best results in orchard spraying at the Maine station were obtained with lime-sulphur 20 per cent stronger than normal, with an addition of 1 pound of dry arsenate of lead to each 50 gallons. This gave the highest percentage of perfect apples, controlled scab better, and caused less russetting than any other combination.

Cherry leaf spot, which was causing serious damage in the State, was effectually controlled by the Wisconsin station by early clean cultivation and spraying with Bordeaux or lime-sulphur with lead arsenate.

Raspberry anthracnose was held in check at the Montana station by four applications of lime-sulphur, applied before the buds open, when the young shoots are from 4 to 6 inches high, again when 8 to 10 inches high, and just before bloom.

Investigations of the brown bark spot disease of fruit trees at the Montana station have led to the belief that it is a nutritional trouble, apparently connected with a shortage of phosphorus and in some cases of nitrogen. While often proving fatal to trees under clean cultivation, it usually disappears with the use of cover crops and improved management.

Two hours' treatment with sulphur was found by the New Hampshire station to kill the spores of snapdragon rust.

Studies of the white pine blister rust at the Connecticut State station have demonstrated that infection takes place through the stomata of the leaves, occurring in late summer, producing minute yellow spots. In the second year the stem is invaded, causing slight swelling and discoloration, which is further increased with possible stunting of the leaves, in the third year. The fungus appears to winter over on the currant under certain conditions.

It was noted at the Vermont station that while Bordeaux had little effect in stimulating growth in the potato, it did control tip burn to a considerable extent. This trouble seems to be due to scorching and has been produced in the greenhouse by mirrors. It occurs when osmotic pressure is low in the leaves. The New Hampshire station is led by its experiments to doubt the direct stimulation of plants by Bordeaux mixture, and it is believed that the effects noted are the result of retarded transpiration due to the shading effect, thus enabling the plant to make a more economical use of a limited water supply. The same effects were produced on plants grown in 40 per cent of sunlight. The New Jersey station also reports no stimulating action of Bordeaux on potatoes, while there did seem to be some from lead salts as far as the tops were concerned.

Experiments on the sterilization of greenhouse soils by steam at the Pennsylvania station have proved the process very effective, 20 minutes giving as good results as 60, and controlling all soil diseases of lettuce. Formaldehyde solution used for this purpose proved to to be of little value.

ENTOMOLOGY AND ZOOLOGY.

Summer fallowing with frequent cultivation is recommended by the Florida station for the control of the root knot nematode. For seed beds applications of sodium cyanid and ammonium sulphate are suggested. Similar recommendations are made by the Alabama station for greenhouse and market garden practice if the value of the crop justifies the expense, which is about $70 per acre. Planting can be safely done about a week after the application of sodium cyanid. The possibility of obtaining fruits and vegetables resistant to root knot is indicated by the result of studies at the Georgia station.

Studies on the field cricket at the South Dakota station show that the females gather in localized areas, preferably where there is no vegetation, to lay their eggs, and an effective means of control is stirring the soil in these areas to bring the eggs to the surface, where they shrivel up in the wind and sun. Other control measures found to be of value are placing hay or straw in the field in which the

crickets gather, and then burning; also poisoned bait, using meat scraps with Paris green or crude white arsenic. The annual loss by injury to binder twine by this insect is very large.

The Oregon station finds that tree crickets may transmit diseases, especially those affecting the bark.

Parasites were found by the Montana station to aid in reducing outbreaks of grasshoppers in many instances. In tests of poisoned bait for this insect at the Indiana station it was found that hardwood sawdust could be substituted in part for bran with a saving of expense. At the Utah station 80 per cent of grasshoppers were killed with a single application of poisoned-bran mash. Unrefined beet molasses was found to be as effective as citrus fruit in the mixture and much cheaper.

Successful control of the sawfly of the plum was accomplished at the South Dakota station by spraying with lead arsenate, 1 pound of the arsenate to 50 gallons of water.

The New Jersey station reports that sodium cyanid is highly effective in controlling the peach-tree borer, when placed around the base of the tree and covered with earth. At the Tennessee station the time of emergence of the adult of this insect was found to vary as much in orchards in the same locality as in widely separated sections, showing that any system of control must be continuous. The use of nicotine sulphate and other insecticides gave largely negative results in experiments at the Maryland station on the control of the oriental peach moth. The applications should be made at least once a month to have much effect. A number of parasites were found that are a material help in its control.

Methods for the control of the rice or corn weevil, worked out at the Alabama station, have been put into practical application through the extension service. The two most important factors in the control of this insect are the selection of a weevil-resistant type of seed corn and the utilization of the trap-plat method of concentrating the first generation in the field where they may be destroyed economically. While diversified farming is being much stimulated in the State by boll-weevil conditions, the injury to corn by this insect is proving a drawback to diversification. A minute parasite of the eggs of the European corn borer has been found by the New York Cornell station, which suggests a practical method of control. A native corn borer, closely related to the European species, was found by the Iowa station to be prevalent in that State, but was not abundant enough to do much damage. It attacks mainly smartweed and wild lettuce, but may be readily transferred to corn. The Kansas station reports that corn plantings in the latter part of April or first of May showed the least corn ear worm infestation.

The best means of control of the wheat stem maggot was found by the South Dakota station to be a poison bait consisting of $\frac{1}{16}$ ounce sodium arsenate, 1 fluid ounce of blackstrap molasses, and 1 quart of water. From studies of the Hessian fly at the Kansas station it was found that it may remain in the straw in the flaxseed stage for four years, if climatic conditions are not favorable for emergence. There may be from one to five broods a year.

An extensive study of leafhoppers by the North Carolina station indicated that they destroy much more pasturage and green forage than is eaten by stock. A species usually feeding on weeds was found to be attacking alfalfa fields. Studies were conducted by the California station on the beet leafhopper (*Euttetix tenella*), in connection with curly top of the sugar beet. Five broods were reared, the first generation completing its life history on the plains and foothills, and four broods on sugar beets and about 35 species of weeds growing in cultivated areas. Swarms of these insects were found to enter the beet fields in the San Joaquin Valley in April, the return flight to the foothills occurring in October and November; hence the beets should be planted in December or January so that the foliage covers the rows before the hoppers come into the field.

At the Kansas station evidence was obtained that the buffalo leafhopper carried raspberry cane blight to young apple trees. The potato leafhopper was found by the Iowa station to winter over in the adult stage. There are two generations a year, one occurring on the early, the second on the late crop. This indicates that it may be possible to control this insect with only one or two sprays. Its connection with "tip burn" was clearly established.

The control of the tobacco flea-beetle, as worked out at the North Carolina station, is based on the destruction of suckers in the fall to prevent overwintering, treatment of the seed with arsenate of lead and lime, and dipping the plants in solutions of this mixture when transplanting. Dusting with arsenate of lead and soda effectively controlled the horse-radish flea-beetle at the New Jersey station.

A study by the Montana station of the influence of the sugar beet louse on the sugar content of the beet showed a difference of 1.1 per cent between infested and noninfested beets, which in a crop of 15 tons to the acre would make a difference of 330 pounds of sugar. The louse can be controlled to a large extent by proper irrigation. Three broods of the sugar-beet webworm were found by the Utah station to be produced during the season, each brood being successively more heavily parasitized, to the extent of 33 per cent in the first, which aids materially in its control.

The Montana station studied cutworms, which did much damage to wheat during the year and found that as a control measure poi-

soned bran mash, dried and run into the ground with a seed drill at right angles to the grain rows, gave good results, catching about 75 per cent of the worms. About 20 species of cutworms were found by the Nebraska station to be injurious to corn, although as a rule only one species predominates in a field. All but two of the species are surface feeders, and a poison bait consisting of 25 pounds of bran, 1 pound of Paris green, ½ gallon of molasses, 3 gallons of water, and 6 lemons was used with success on alfalfa fields, the above amount being sufficient for 5 acres. A parasitic fly was found that destroys the variegated cutworm, sometimes entirely controlling it.

Wireworms and false wireworms, which have been very destructive to wheat in the drier sections, have been studied at the Washington station, where poisoned baits of sodium cyanid in rice balls or Irish potato have been very successful in their control. Summer fallow does not eliminate them because the larval stage is three years.

A cryptothrips has been found to be quite injurious to camphor trees, by the Florida station. It was controlled by spraying with tobacco and lime sulphur. The velvet bean caterpillar was found to attack the Florida velvet bean by preference, so that this may be used as a trap crop if planted with other varieties.

The importation of parasites from Cuba by the Louisiana station has given encouraging results in checking cane insects.

The clover aphis, which seriously threatened the crop in Idaho, was found by the station to be controlled by grazing with sheep and spraying. The control of the vegetable aphids was shown by the New Jersey station to be possible by the use of nicotine, soap, and water sprayed on the plants at high pressure as soon as the insects appear. The California station has successfully controlled the walnut aphis by the use of a dusting mixture composed of clay, hydrated lime, and 40 per cent nicotine sulphate, dried and pulverized. The Oregon station finds that the number of progeny of apple aphids varies directly with the rapidity of atmospheric evaporation, which also affects the period of development and the seasonal migration. *A. sorbi* was found to winter on the plaintain but may spend the whole summer on the apple.

The green aphis, which causes serious dwarfing of young apples and also causes fruit buds to change to leaf buds, was controlled at the New York State station by delayed dormant spraying with lime-sulphur. The Colorado station finds that the dogwood is apparently the only winter host of the aphis attacking the sunflower, which latter is now being extensively planted for silage. As this is proving to be a rather serious pest, its control may require the eradication of the dogwood. Nicotine sulphate, 40 per cent, and kerosene emulsion were successfully used by the Arkansas station to control both the cabbage worm and aphis. The apple woolly

aphis was found to have new generations about every 10 days through the summer. One of the pink and green aphids of the rose was found by the Maine station to cause wilt on the potato.

The Indiana station finds that in that State there are no well defined broods of the codling moth but rather a continuous succession from spring to fall, necessitating spraying every 10 days or 2 weeks throughout the season. At the New Mexico station it has been shown that while there is considerable overlapping of the broods in the summer most of the eggs are laid during July and August, the spring brood being comparatively small.

The egg-laying period of the pear psylla is not completed before blooming, according to observations by the New Jersey station. Consequently, spraying before this time is not entirely successful. Scraping during the dormant period has little effect, but winter treatment with a soluble oil is important. The late brood of Psylla can be checked with self-boiled lime sulphur, without danger of burning. A species of golden rod, *Solidago altissima*, is found by the Kentucky station to be a host of the locust borer, and locust trees are most attacked in localities where this species grows, little trouble being encountered where it does not occur.

Life-history studies of the clover leaf-beetle at the New York Cornell station shows that in favorable years there are two broods. Late in the season many of the beetles were found to be parasitized. The control of the meadow plant bug, feeding especially upon timothy, is believed by the Maine station to be mainly by rotations, with some advantage in burning, early cutting, and pasturing heavily in the fall.

Tobacco dust heaped about the plants gave effective control of the cabbage maggot at the New Hampshire station. By the use of a bait consisting of 2 quarts of molasses, 1 gallon water and 1 ounce of sodium arsenate, put in small containers 50 feet apart, losses from the onion magggot were cut down from 50 per cent to less than 5 per cent at the New Jersey station. The New York Cornell station controlled apple and cherry maggots by the use of poisoned baits.

The metabolism of the bean weevil was found by the New York Cornell station to be greatly affected by variations in atmospheric moisture, and it is believed that the utilization of a low humidity in storage may provide a satisfactory method of control.

Spraying with nicotine solution has proved satisfactory for the control of the chrysanthemum midge at the Connecticut State station.

The important discovery was made by the Pennsylvania station in connection with an outbreak of red spider that the insect concerned was an imported form, *Paratetranchyus pilosus*, not before

reported as occurring in the United States. It is suspected that this may be the insect causing serious damage to the apple, prune, and cherry in the State.

The Oklahoma station finds that two years are required for the development of the fish moth and that two broods a year are produced.

Soluble oil sprays are recommended by the Arkansas station for the San Jose scale, but dry lime-sulphur is also found to be very effective.

Sweet-potato weevil studies at the Texas station showed that the total period of the adult life may be over eight months, with an oviposition period of seven months.

Bee studies at the Iowa station showed that field bees average 82 milligrams in weight and can carry from one-half to three-fourths of their weight in nectar, requiring about an hour for the round trip in gathering honey. At the Indiana station the placing of hives of bees under screens with sprayed trees resulted in the death of many of the bees.

Mosquito control studies at the New Jersey station have given a marked degree of protection.

Life histories of the biting flies of cattle, especially the tabanids, have been worked out at the Nevada station. A study of the most serious of these, *T. phænops*, shows that on account of the moisture requirements of the larvæ, drainage of lowlands in which they breed offers a practical means of control. While the larvæ may live when the soil becomes dry, they do not range through the soil for food, and so they die of starvation, and the mature females do not lay eggs under these conditions.

Cereal insects in storage were controlled at the Ohio station by maintaining a temperature of 130° to 140° F. for 4 days.

The Maryland station found creosote emulsions, sprayed on the ground as repellents for ants to be somewhat injurious to germination under excessive moisture conditions if used stronger than a 0.5 to 1 per cent emulsion. Strengths above this were also injurious to plants when used as a spray. The South Carolina station found that cover crops of rye and oats drive off the ants attendant upon the activities of the cotton root-louse.

From data based upon 10 years of study of the relation of temperature and moisture to insect activities at the South Carolina station it is now possible to predict the prevalence of certain insects with considerable certainty. Thus, it is found that the minimum winter temperature has a determining influence on the red spider and its natural enemies; that cold, humid winters are favorable for aphid development, and that 12 per cent of soil moisture causes wireworms to disappear.

Studies at the Minnesota station on the toxicity of chemicals to insects show that in contact insecticides this rests largely on the power of vapors to penetrate the chitinous coat of the insects. The control of truck-crop insects with arsenical sprays was found to rest largely on the mechanics of application. Similar investigations at the Oregon station showed that the paste forms of lead arsenates are inferior to the powdered forms in toxic effect. The commercial powders vary greatly in their physical character. Those brands that are uniformly finely divided stay in suspension longer and show a higher degree of control effects. The physical properties of the spray solution may be materially improved by the use of organic spreaders, such as calcium caseinate, saponin, gelatin, or glue. The better brands of calcium arsenates were slightly superior, pound for pound, to the average lead arsenates as a poison for codling-moth larvæ.

A study of the insecticidal properties of pyrethrum powder for plant lice at the New Hampshire station showed the pure powder to have 100 per cent efficiency, but when the powder was mixed with flour the efficiency was diminished in proportion to the dilution.

Investigations on crawfish at the Mississippi station have resulted in finding at least two new species. The prairie-land crawfish burrows down to water, sometimes to a depth of 18 feet, coming to the surface at night, doing considerable damage to corn and cotton. The species inhabiting the dikes and levees rarely burrows over 5½ feet.

A determination of the destructiveness of ground squirrels to wheat at the Washington station indicated that each squirrel costs the farmer from 35 to 50 pounds in reduced yields. The Arizona station has undertaken an investigation in rodent control in connection with range injury. The kangaroo rat, while living mostly on air-dry food, will eat green food material. The breeding season is irregularly distributed, but apparently occurs only once a year, the females producing only one or two young under desert conditions.

FOODS AND NUTRITION.

Several stations, notably Connecticut State, Minnesota, and Wisconsin, have devoted much attention to studies of the vitamines, their relation to nutrition and to deficiency diseases. The vitamine content of milk was found by the Minnesota station to be dependent on the diet of the cow. Raw lean beef contains no antiscorbutic principle, but rhubarb and tomato juice were found to be as efficient as orange juice in this respect.

The studies carried on by the Connecticut State station continue to yield valuable contributions in this important field, especially as regards the sources and occurrence of the vitamines and their influence on growth. Water-soluble vitamines have been isolated and

purified in sufficient amounts for experimental study, and their importance as an essential food constituent for the maintenance of the healthy condition of animals has been demonstrated. Clover, spinach, cabbage, and some other green vegetables were found to be important sources of these materials, and studies are being made of their occurrence in seeds, tubers, etc.

At the Oregon station it was demonstrated that skim milk contains sufficient fat-soluble A vitamine to produce satisfactory growth in dairy calves.

Among the vegetable proteins studied at the Connecticut State station zein from corn proved to be the least efficient for promoting growth. The best growth was obtained when a mixture of vegetable and animal proteins was fed. When a considerable portion of the endosperm of the wheat grain was removed there was found to be a reduction in the food value of the flour.

A study by the Wisconsin station of the proteins of the home-grown feeds ordinarily used on the dairy farm for milk production showed that it was not possible to furnish dairy cows of high milk-producing capacity with a protein content of sufficient amount or quality to maintain maximum production from a clover hay, corn silage, and cereal-grain mixture. This should be supplemented with any of the plant protein concentrates, such as the oil meals.

The importance of more careful attention to the mineral constituents in animal nutrition is well brought out by investigations at the Wisconsin station on the part played by calcium in reproduction. Animals fed a ration deficient in calcium, for example, as whole oats and oat straw, produced dead offspring, while the addition of 2 pounds of calcium acetate to each 100 pounds of grain entirely corrected the trouble. The need for calcium is paramount even as to maintenance of bodily weight and vigor, and is apparently independent of the demand for it as a base to neutralize acids in the body. When grains made up the sole diet, fortified only with salt and a naturally hard water, mature sows could be maintained in fairly good condition for a few months, but eventually went to pieces. No one grain was distinctly inferior to others in this respect, although earlier ill effects were noted when barley was used alone than with corn or oats. It is now being recognized that roughages are important carriers of mineral materials as well as the growth-stimulating vitamines.

The work on the mineral metabolism of animals at the Ohio station shows that a liberal milk production involves a certain degree of impoverishment of the skeleton in mineral substances; that rations containing no legume roughage are apt to be definitely lacking in mineral nutrients, especially calcium; that the response of heavily producing cows to a liberal intake of mineral nutrient is remarkable for its inefficiency, at least during the early part of the period of lac-

ation; and that the mineral constituents of the skeleton appear to e more readily available for use in milk secretion than are nutrients irectly absorbed through the ration.

Investigations on the nutrition of calves at the Indiana station ave resulted in a formula for a successful milk substitute composed f 12 parts of dried blood, 8 parts of corn meal, and 1 part of oil meal, ie experiments showing that the gain in weight per gram of nitrogen onsumed with this substance is approximately the same as the gain er gram of nitrogen when on a milk diet, and the mixture is readily igested and assimilated.

A series of cooperative experiments have been carried on by a num- er of stations on the maintenance, growth, and milk production equirements of cows. The Virginia station found that the feeding f a high protein ration to calves was as economical and more efficient ian a low one. Those receiving a low protein ration were less effi- ient in digesting this food element than those receiving a high pro- in ration. In an experiment by the same station on the require- ients for milk production, one animal was fed a bare maintenance rotein with a high energy ration, another receiving a high protein ith a relatively low energy ration. The digestibility was much ffected by these combinations, the coefficient of digestibility of all ie nutrients being very much reduced in the low protein and high iergy animal, resulting in a protein starvation and consequent rapid ss of flesh when milk was being produced, although under normal onditions the protein should have been sufficient. The animal re- iving the high protein and low energy ration digested a large mount of protein in excess of the requirements for maintenance and ilk production, and the coefficient of digestibility of the nitrogen- ee extract was slightly above the average.

A study of the effect of grain rations on the growth of chicks at the entucky station showed that the proteins of rice, oats, barley, hominy id gluten flour were inefficient in producing normal growth in the hite Leghorn chick.

ANIMAL INDUSTRY.

Experiments at the Montana station in winter feeding the breeding erd showed that if the cows are strong and fat in the fall they may e wintered on straw alone, with no bad effect on the calves the fol- wing summer, if the cows have plenty of good water and salt. Sup- ementing the straw with a little cottonseed meal was of consid- able benefit. At the North Dakota station cattle were wintered on arley and bran, with no corn, and finished exceptionally well. One undred and seven pounds of barley was equivalent to 100 pounds of rn.

Experiments at the New Mexico station on the value of soapweed (*Yucca elata*) for the maintenance of range breeding cows showed

that 28 to 30 pounds of this material with 1 pound of cottonseed meal per 1,000 pounds of live weight was sufficient to maintain the cows unless they were suckling calves. After the animals had been accustomed to the feed they could be maintained on slightly less than at first. Those receiving the cottonseed meal supplement came through in excellent physical condition, while one lot fed Yucca alone showed signs of malnutrition. These results are confirmed by similar experiments at the Texas station.

The advantage of supplementing range feed was demonstrated at the New Mexico station with two lots of cows, one kept on the open range without other feed, the other receiving a light allowance of cowpea hay and kafir silage. The calves of the latter lot averaged 11 pounds more per head than those of the first lot.

White sage, which is considered an ideal winter range plant, has been eradicated in many sections by overgrazing. Valuable information in regard to seed germination, means of dissemination, and the proper depth of seeding have been worked out by the Nevada station.

In a comparison at the Colorado station of ground barley and oats with corn, supplemented in each case with cottonseed meal, for fattening steers, the lot that were fed barley and oats made as good gains as the corn-fed lot and at less cost, but did not show quite as much finish at the close of the test. The best results in feeding sugar-beet tops to fattening steers at this station were obtained by pasturing in the field.

In three years' cattle feeding experiments at the Oregon station steers fed for 80 days on a ration of 13 pounds of mixed grain, 13 pounds of silage, and 13 pounds of hay gained on an average 2.91 pounds daily. Feeding experiments at the Nebraska station showed no profit from the introduction of oil meal in the ration, but hominy feed was fed at a profit and the steers were better finished. At the Pennsylvania station, feeding tests indicated that at the present price of feeds it was more economical to use protein concentrates, as linseed or cottonseed meal, during the latter part of the finishing period, than to finish with corn.

At the Florida station a comparison was made of velvet-bean meal and peanut meal, both fed with corn, for fattening steers. Both lots made practically the same gains, but the peanut-meal lot cost a little more. When marketed the steers were classed as the best ever received at the Jacksonville market. No softening of the fat of the peanut-fed lot was noticed. In experiments at the Alabama station to determine how many pounds of velvet beans in the pod will produce 1 pound of beef, six yearling steers, with an initial weight of 900 pounds, on a 2-acre plat carrying about 614 pounds of beans to the acre, and with a supplementary forage of cornstalks, required from 4 to 6 pounds of beans to produce a pound of gain.

The Illinois station has demonstrated the feasibility of making a good silage from shock corn stover, producing an economic roughage for the maintenance of cattle. The stover should be cut and put in the silo with an equal amount of water. The product is somewhat less acid than that made from green corn. By supplementing this with 1 pound of linseed or cottonseed meal per day per 100 pounds live weight, the body weight was maintained at a cost of 7 cents per day.

The results at the Montana station of wintering sheep on sunflower silage, supplemented with a little cottonseed cake, have been very favorable, $2\frac{1}{2}$ pounds of the silage being equivalent to 1 pound of hay. The introduction of oil meal in the ration for fattening lambs at the Nebraska station showed no profit, but hominy feed both increased the rate of gain and decreased the cost per 100 pounds. At the Washington station a comparison of pea straw and alfalfa hay as a winter roughage for lambs and pregnant ewes resulted slightly in favor of the pea straw as to cost. Although the lot receiving this required a little more grain the difference was not great. The most profitable ration for feeding lambs at the Iowa station, comparing a large variety of feeds, was shelled corn full-fed daily, with 15 pounds of linseed meal, daily per lamb, fed on corn silage full-fed twice daily, plus clover hay full-fed overnight, with salt at will. The lambs returned a margin of $3.32 over feed cost per head.

At the Wyoming station, in a comparison of native hay and silage with alfalfa for breeding ewes, the ewes on alfalfa did better and made more rapid gains but at greater cost. Strong young ewes did very well on native hay. A study of the cost of producing spring lambs at the Oregon station showed that native pastures will average 800 to 900 sheep days per acre, while cultivated crops will give from 1,000 to 1,200 sheep days. Of the latter, rape, vetch and oats, or rape and clover are available. The cost on native grasses was 5 to 6 mills per sheep per day. Sheep without shelter gave better results than those in confinement, a shed closed on two sides to protect from wind and rain being sufficient. It required on an average 1.06 acres of pasture to sustain one sheep for a year.

The Nevada station has found that losses on the range in the lambing season are largely a question of feed, and that alfalfa or meadow and swale hay must be supplemented to keep up a sufficient milk flow to prevent the losses. Sheep grazing upon feterita at the Texas station were found to be susceptible to the prussic acid in this crop, as are cattle.

In attempts to establish a breed of sheep for winter lambing, the Oklahoma station finds that early breeding is a dominant character of the Dorsets, which can be established by selecting those individuals that are born in the fall and have proved themselves to be early

breeders. The character can also be fixed in the higher crosses. Considerable progress has been made at the South Dakota station in breeding a tailless strain of sheep, with good vigor and quality of fleece, by crossing native varieties with tailless sheep imported from Siberia.

Investigations at the Montana station on factors affecting the character of wool showed that range sheep give a much weaker fiber and much more variation than barn-sheltered sheep. The factors that affect the strength also affect the diameter and there appears to be a correlation between these. The fiber is also affected by the feed. When well-fed and well-managed sheep are changed to a poor feed, a decided change is shown in the wool at that time. Humidity exerts more influence on the properties of wool than temperature, within certain limits.

Similar studies at the Wyoming station indicate that when the relative humidity increases from 40 to 80 per cent there is a decrease in breaking strength but an increase in elasticity. Above 80 per cent the elasticity begins to decrease and the breaking strength to increase slightly. The tensile strength decreases as the size of the fiber increases. The breaking strength is a better measure for comparison between the different grades than the tensile strength, especially with the finer wools. With the coarser fibers the tensile strength seems to be correlated to the diameter, with a figure lying somewhere between the first and second power, but in the finer fibers it is in closer correlation to the first power of the diameter than to the second power. Negative results were obtained so far as the effects of alkali and weather on the wool of live sheep were concerned, but in small flocks exposed to the weather the wool decreased 30 per cent in strength in one month and at the end of three months the fibers were destroyed. Feeding inorganic sulphur had no effect on the wool.

A number of the southern stations have investigated the relation of peanut feed to softness and other changes in pork. A series of feeding experiments were carried out at the Alabama station with lots receiving increasing percentages of peanuts with corn, compared with a check lot receiving corn and tankage only. All of the lots finished well, but the check lot was the best. No bad effect on the fat was noted when the peanut meal was fed in amounts sufficient to give a balanced ration. Most of the lots were classed as firm, although those receiving the largest percentage of peanut meal were classed by some of the judges as medium firm. Other experiments were conducted to determine the effect of dry lot feeding on the quality of the pork, and if it was profitable to finish off soft hogs in this way. Two lots that had been on peanut pasture for eight weeks were fed in the dry lot, one receiving corn and tankage, the other, peanuts only. The corn-and-tankage lot brought half a cent a

ound more than the other, and the dry lot finishing and hardening vas conducted at a profit. Two lots of hogs were pastured on peanuts or 30 to 40 days, at the Oklahoma station, one lot finished on cotton-eed meal, kafir, and alfalfa, the other on tankage, barley, and lfalfa; both gave pork that was classed by packers as soft, although here was a rise in the melting point of the fat of the tankage lot of ½° C.

Investigations at the Texas station indicate that exposure as well s feed, may produce a soft pork and that other factors such as breed, nanagement, degree of finish, and health also have an influence. he best results with peanuts were obtained where these did not onstitute more than a third of the ration. Two parts of corn with ne part of peanut meal gave a hard pork. The best results were btained by providing shelter with a lot to run in.

Experiments at the Montana station on the proper amount of rain for hogs in connection with forage crops indicate that a light rain ration is most economical. When a full grain ration was fed ogs could be finished in 20 to 30 days, but a lighter ration fed dur-ng the finishing period, from 1 to 2 pounds per 100 pounds of live veight, made the cheapest pig. The advantage of supplementing asture and forage with some grain was brought out by experiments t the Virginia station, in which pigs receiving the largest grain llowance gave the best returns. Peas proved to be a very satis-actory pasture crop for hogs at the Washington station. The ddition of a 2 per cent grain ration did not prove profitable. Pigs astured on alfalfa with no supplementary feed did not make satis-actory gains.

A comparison of fish meal as a substitute for tankage in a corn ation at the Missouri station demonstrated the value of this com-aratively new material. In all cases the hogs receiving it made a nore rapid gain and required less feed to produce a given amount of ain. The Alabama station also reports satisfactory results with sh meal. That station also finds that no bad results followed the eding of velvet beans to pregnant sows. The value of soy-bean orage in pork production was demonstrated at the Delaware station, here 1 acre of the beans supplemented with $89.97 worth of grain, roduced 1,127.5 pounds of pork.

In a study of economical rations for pork production at the ebraska station tankage was found to be preferable to shorts when d in a self-feeder to supplement corn and alfalfa, increasing the net rofit per pig. Hominy feed made a satisfactory substitute for corn t the Missouri station, although hogs getting this gained a little ss rapidly and required slightly more feed to produce a given mount of gain than corn-fed hogs. Practically the same conclu-ons were reached in using barley as a substitute for corn. A com-

parison of barley and corn at the Iowa station showed the former to be excellent for brood sows, but not quite equal to the latter for fattening hogs. One hundred pounds of corn was equal to about 124 pounds of barley for this purpose, but the barley made an excellent quality of pork.

Pigs fed by the New Jersey station on garbage with 1 per cent shelled corn made satisfactory gains. Raw garbage alone produced more pork in a given time than cooked garbage alone, although neither gave as good gains as garbage finished with grain for the last 35 days of feeding. At the Oregon station 125 hogs were fed for two months on garbage, each one consuming on an average the garbage from 16 men, with a supplement of 2.38 pounds of barley, and gained 1.57 pounds daily. Making allowance for the barley consumed, the garbage from 1 man for 1 day produced 0.965 pounds of pork worth, at 18 cents a pound, 17 cents. The feeding value of garbage from a training camp was found by the Mississippi station to be $1.16 per 100 pounds. At the Michigan station 1 ton of garbage produced approximately 100 pounds of pork, and about 500 pounds of garbage was equivalent to 100 pounds of grain. The material, which was gathered daily from students' boarding clubs, gave better results when cooked. In garbage feeding experiments at the Oklahoma station 100 pounds of pork was produced from 1,177 pounds.

Adding molasses to grain feed at the Oregon station resulted in more feed being consumed and better gains obtained. Oats did not prove to be a profitable feed for hogs at the Oklahoma station. The use of self-feeders for fattening hogs at the Arkansas station reduced the labor about 50 per cent. Runts separated from more vigorous and larger pigs, and fed carefully with nutritious feeds, made rapid and economical gains at the Oregon station. Studies on the effect of acid in the feed of swine at the Iowa station demonstrated that mineral acids, even in large doses, failed to cause a significant loss of calcium or to interfere with the storage of protein.

An investigation on the effect of age of pigs on the rate and economy of gains at the Ohio station confirmed the general experience that the feed requirement per unit of gain increases with increase in weight, and that the dressing percentage of full-fed pigs also increases with weight.

At the Michigan station it was found that mature horses can be carried over the winter on silage and straw, providing the silage is of good quality, but young horses are not properly nourished by such a ration.

The Kentucky station reports that in its horse-breeding experiments approximately one-half of the mares bred proved to be sterile. This was found to be due to methods of breeding, to mares with

diseased organs, or to stallions partially or wholly impotent. In the latter case changes in exercise and diet, aided by tonics, helped in many cases.

In poultry feeding experiments at the North Carolina station, hens fed in the dry lot produced an average of 35.7 eggs per year as compared with 76.4 eggs per hen for range feeding. Experiments at the Missouri station showed that the efficiency of a ration for egg production is greatly increased by including a protein supplement from animal sources. Where no animal food was used it required from 12.3 to 14.25 pounds of grain to produce a dozen eggs, while with animal food this was reduced to 8.25 to 9.05 pounds. Cottonseed meal did not materially increase the efficiency of the ration, but sour milk proved to be about equal to meat scraps. Similar results were obtained at the Iowa station, where it was shown that a large percentage of animal food is needed for winter egg production, the mash containing the largest amount of protein giving the largest number of eggs at least cost. At the Indiana station soybean meal, especially when supplemented with a suitable mineral mixture, proved to be a good feed for supplying protein to young chicks.

Pullets allowed free range at the Connecticut Storrs station showed 70 per cent hatchability of their eggs as compared with 44 per cent with no range. Those on range laid 740 more eggs in two years than the confined lot.

Studies on the relation of plant carotinoids to poultry production at the Missouri station led to the conclusion that the natural yellow pigment of fowls, which is derived from the xanthophyl of the food, bears no important relation to fecundity and reproduction, at least for one generation. When rations devoid of xanthophyl were fed to cockerels, the yellow pigmentation in the skin, beak, shanks, ear lobes, etc., gradually disappeared. The shanks of laying birds fade when egg-laying begins, and if this is continuous the shanks of even the yellow-skinned varieties will in time be entirely free from pigment. The explanation of this is that egg-laying deflects the normal path of excretion of xanthophyl from the skin to the egg yolk. At the Michigan station the egg yolk color was found to be intensified by feeding lobster shells.

Broodiness in poultry has been under investigation at the Massachusetts station. Nonbroodiness appears to be a recessive factor and is much more difficult to establish than broodiness. When a bird becomes broody, its temperature declines about one degree.

The Rhode Island station finds that high-producing ability is better shown by the weight of eggs than by the count.

Incubation studies at the New Jersey station indicate that the vital times for turning eggs are during the first week and just before

hatching, turning between these periods being unnecessary. Cooling retards the development of the embryo and is not necessary if the incubator is well ventilated.

At the California station artificial lighting of the henhouse increased the egg production in winter up to 60 per cent, the effect being to change the laying season, giving more eggs in winter but no more for the entire year. The effects were more marked with pullets than with hens. At the New Jersey station this practice increased production 100 per cent from November to February, and the net returns from feed cost over 400 per cent. At the Utah station also profitable increase in egg production was secured from lighting during the winter, but with only slight increase in the yearly production. The eggs from the lighted houses showed as high a percentage of fertility as those from unlighted houses.

DAIRY HUSBANDRY.

The effect of peanut meal fed to dairy cows on the quality of the butter fat was found by the Georgia station to be no greater than that exerted by the roughage in the ration.

A comparison at the South Dakota station of gluten feed with oil meals for the protein supply in the dairy ration, showed that only about half as much protein in the former is required to reach the nitrogen balance as in the latter. The adaptability of individual animals to the various proteins is a disturbing factor in getting reliable data on such problems.

From studies at the California station on the effect of barley on the milk secretion of cows, this grain was found to be excellent for dairy cows and no deleterious effect was noted on the milk when the ration fed contained sufficient nutriment. The use of barley, both for dairy and for stock feeding, is recommended when its market value makes it economical in comparison with other concentrates.

The Ohio station, comparing clover and alfalfa hay, found that while a preference was manifested for the alfalfa, and more of it was consumed, the production of milk per unit of protein consumed was greatest with clover. In experiments on methods of feeding velvet beans at the Alabama station bean and pod meal was the most satisfactory and palatable, and the soaked beans were better than those fed whole and dry. It is not advisable, however, to make the entire ration of velvet beans.

Feeding experiments with sunflowers, both green and as silage, for dairy cattle gave excellent results at the Montana station. The green sunflowers were found to be equal to green clover pound for pound. One pound of alfalfa hay was equivalent to 2.83 pounds of sunflower silage, the latter being considerably cheaper. At the

New Mexico station, sunflower silage gave as good results as cane silage for milk production, and velvet-bean meal was found to compare favorably with wheat bran.

Experiments at the Oregon station showed that young dairy cattle can be wintered satisfactorily on straw, molasses, and a small amount of grain, at a cost of from 30 to 40 per cent less than with clover hay. Barley compared well with bean and shorts for maintenance but did not fatten the cows. It was found that coconut meal could replace cottonseed meal in part for milk production without loss. Cottonseed hulls and corncob meal were found to have about the same value in feeding trials at the Mississippi station. A comparison of the effect on production of early and late fall calving at that station showed the advantage of the latter. Late fall calving cows milked 44 weeks compared with 48 weeks for the early calving cows, but gave 716 pounds more milk and 30.3 pounds more butter fat. The Iowa station also found that the time of freshening has a considerable influence on production, fall freshening giving about 10 per cent more than spring or summer.

From three years' trials of milking machines at the California station it is concluded that the modern machine is a practical and safe labor-saving device, giving as good results as regards the production of milk and butter fat during the lactation period as does hand milking if equal care is used.

A study of the hydrogen-ion concentration in milk as influenced by various factors at the New York State station indicate that this can be used for the rapid detection of abnormal milk. Under normal conditions 6.5 represents the highest acidity of normal milk. At the Michigan station a method has been devised for determining the keeping quality of milk by a colorimetric hydrogen-ion determination, whereby it is possible to predict the length of time required for a sample of milk to curdle. This method gives a very effective means of checking up market milk supplies, both more accurate and less complicated than the bacterial count method. The Wisconsin station has devised a very simple and rapid method of testing milk from a hygienic standpoint which consists in adding a minute quantity of methylene blue. The rapidity with which the color disappears is directly related to the bacterial content of the milk.

Studies on the keeping quality of butter at the Minnesota station show that heating the cream to a point high enough to destroy many or all of the enzyms present as well as the bacteria, which can be done at 175° F., will produce a butter with materially better keeping qualities than if the cream is heated to the usual temperature of 145°. Results of trials of the neutralization of the acidity of cream for butter making at the Oregon station showed without exception that butter made from such cream had better keeping qualities than that from

untreated cream. Studies at the Indiana station indicate that, in general, less change takes place in butter made from sweet than in that made from sour cream.

The Vermont station has successfully stored cottage cheese for four or five months, the product then scoring high with experts. Cheese from pasteurized milk kept a little better. Attempts at the South Dakota station to make a skim milk cheese that would keep showed this to be possible, but the results were not entirely satisfactory as the cheese tended to become hard from lack of moisture and the flavor deteriorated. Similar results were obtained at the Idaho station, when the flavor deteriorated rapidly at 50°, more as a result of acids formed by bacteria than of molds and yeast. After about 15 days the cheese was no longer marketable. Salting and washing reduced the bacterial count to some extent. A test of whey separators at the North Carolina station showed that 2½ pounds of fat may be recovered from 1,000 pounds of whey.

VETERINARY MEDICINE.

Contagious abortion has been investigated at a number of the stations. The Minnesota station believes the blood test to be of little value. Vaccine has been used with some success. A study at the Wyoming station showed that 50 per cent of cows that aborted became sterile from closure of the mouth of the uterus. Some success followed the use of spring wire pessaries to prevent this. Studies of the immunization of horses and cattle against abortion at the Kentucky station indicate that bacterin vaccination constitutes a reliable means of preventing the disease in mares. The treatment should be given before they are infected, three inoculations 7 to 8 days apart being recommended. The results with cattle have not been so encouraging.

From a large number of tests the Connecticut Storrs station finds that calves without exception give the same agglutination reaction as their mothers, and that after the sixth month all calves are nonreactors. The greatest danger from infection exists at the time of sexual maturity and for several months following, and if heifers are safeguarded against infection from without they remain uninfected indefinitely. Whether they were reactors or not at their birth has no bearing on the readiness with which they become infected at or after maturity nor upon their breeding record. Repeated efforts to infect calves, heifers, and cows by feeding *Bacillus abortus* in capsules and milk proved complete failures. The results of five years' study very strongly indicate that the male is the most important factor in the transmission of the disease, and disinfection of the sheath of the male is therefore an important means of prevention.

The Oregon station finds that one of the common sources of infection is pen exposure of pregnant animals. From studies on the effect of food on abortion at the Maryland station it is believed that in general the substitution of corn for wheat products has reduced this trouble in the herd.

Positive results have been obtained at the Alabama station in the transmission of hog cholera by lice, both by injecting with extracts of the insect and by transferring from infected hogs. At the Indiana station sterile earth saturated with blood of an infected hog fed to a healthy animal produced symptoms up to five days, similar tests with urine and feces not being so positive. Attempts to transmit the disease by house and stable flies gave negative results. Experiments have been made at the North Dakota station to attenuate hog-cholera virus through other nonsusceptible species, as goats and rabbits, and the evidence indicates that a 10 days' sojourn of the virus in the rabbit robs it of its disease-producing property, but susceptible pigs died of cholera following injections with the blood of rabbits which had been inoculated 5 to 7 days previously. In both peccaries and goats infectiousness was carried through four generations. Dilution experiments showed that 1/400 cubic centimeter of the virus was sufficient to produce the disease.

The California station finds that in making the tuberculin test on cattle there is a small but constant percentage of reactors that do not show local reaction until later, and that early observations can not be depended on. Two observations are recommended, one at 48 to 60 hours after injection and one at 96 to 120 hours.

A study of the extent to which infected environment may be responsible for the spread of the disease showed that tuberculous material placed in 1½ inch thickness of manure in a small pen in which cattle were exposed to the dust lost its infectiousness after 17 days if no rains intervened. In water holes, on the other hand, or if the material was kept moist, it was infectious to guinea pigs for 687 days. Two out of three cattle became tuberculous when forced to drink water taken from water holes 149 days after such holes were infected. This leads to the conclusion that environment contaminated with tuberculous discharges from cattle loses its infectiousness rapidly after the media lose their sensible moisture, but that the tubercle bacilli retain their virulence for long periods in such places as water holes, mud holes, and watering troughs.

This station has also investigated a disease known as lymphangitis in cattle, the casual organism of which closely resembles the tubercle bacillus, and a large percentage of the cases gave positive reactions with the intradermal tuberculin test, although tuberculosis could not be found on autopsy.

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That swamp fever of horses can be transmitted by certain flies has been confirmed by the Wyoming station. Mild cases showing no symptoms often serve as carriers, and it will be necessary to find some diagnostic test to recognize these. Besides its transmission by insects, especially those with habits of interrupted feeding, the disease may be transmitted by introducing the nasal discharge from a sick horse into the nasal cavity of a healthy one, and in some cases may be transmitted by food contaminated with urine. Mosquitoes, especially from their manner of feeding and the structure of their mouth parts, do not appear to carry it. The blood of an infected horse is only virulent at certain times. The mortality of acute cases is very high. The North Dakota station has also investigated this disease and finds that if the blood of an infected horse is heated to 60° C. it loses its virulence. The infection may be carried by the urine as well as the blood and is also transmitted in the milk to the young, as nursing colts receiving no other food become infected.

The Wyoming station has also studied and isolated the organism of necrobacillosis. This organism does not invade the blood stream but remains near the point of infection, the lesion produced being wholly local, consisting of necrosis but with no pus formation. The same organism, apparently, according to the place of infection, may produce calf diphtheria, stomatitis in calves and pigs, pneumonia in calves, lambs, and pigs, necrotic enteris, necrotic dermatitis, and lip and leg ulceration in sheep. The organism grows only in an atmosphere of nitrogen and no good medium has been found for it, but it may be kept by inoculating rabbits.

Studies on the cause of "trembles" in farm animals, by the North Carolina station, which have definitely shown it to be caused by rich weed (*Eupatorium ageratoides*) also show that another common species of this genus, *E. incarnatum*, apparently does not cause the disease.

Results of experiments with nonbiting flies, particularly the house and maggot flies, at the Louisiana station show that these insects can carry anthrax infection to wounds on otherwise healthy animals after feeding upon anthrax-infected flesh or upon the discharges from carbuncular swellings on animals sick with anthrax, indicating the necessity for prompt and complete destruction of all anthrax carcasses and also of giving animals greater protection against the ravages of all insects during outbreaks of the disease.

From studies at the Kentucky station it is believed that clover bloat in cattle does not ordinarily take place unless there is some indigestion. Its artificial production by feeding clover blossoms even with glucose and yeast, was not always successful.

At the West Virginia station it is found that newly hatched lungworms of calves will live for long periods at a temperature of 32° F.,

nd that eggs will hatch after being exposed to extreme cold for 35 lays.

Studies on an unidentified hemorrhagic disease in cattle at the Nevada station resulted in a serum that has been quite successful in ts control. The specific organism has not been found.

Investigation by the Wyoming station on the sarcocystic parasites of sheep indicate that infection is seasonal, occurring during summer nd early fall, and that it is usually from grass contaminated with droppings. Progress has been made at the Texas station in producng a serum for treatment of swell head of sheep and goats. Goiter nd hairlessness in Angora goats was effectually controlled at the Washington station by pouring 1 cubic centimeter of tincture of iodin on the skin once every two weeks throughout pregnancy.

The Nebraska station finds that rabbits, poultry, and guinea pigs re susceptible to hemorrhagic septicemia, but has not been successful n inoculating it into cattle or horses. It may be successfully inoculated into hogs when they are recovering from cholera. Blood from n inoculated horse seems to have some immunizing qualities on abbits. The causal organism has been found in cattle and swine.

At the Minnesota station experimental infections of the preventricuar and gizzard worms of fowls were unsuccessful. The bacillus of acillary white diarrhea of poultry was isolated by that station. The New Jersey station has been very successful in the preparation f autogenous vaccines for chicken pox, roup, and canker. Tobacco lust as a vermifuge for the control of intestinal roundworms in oultry has given excellent results at the California station. Studies n the tapeworm of poultry, *Hymenolepis caroica*, by the Oklahoma tation show that the intermediate stage is passed in the stable fly, nd the parasite has been transmitted by feeding these flies to chickns. Life-history studies of the chicken tapeworm, *Choanotœnia nfundibuliformis*, at the Kansas station show that this is transmitted y the common house fly as an intermediate host.

A number of stations have been engaged in investigations on oisonous plants. It was found at the Montana station that an verage acre of loco weed can be grubbed out by one man in about even hours. All of the so-called loco weeds are not harmful. Studies t the Oregon station show that plants not usually regarded as angerous may cause trouble under certain conditions. Thus, a cress *Radicula* sp.) is suspected of being the chief cause of a serious outreak of cattle poisoning although this plant has not hitherto been eported as poisonous.

Increasing losses on the Nevada ranges have led to an extensive tudy of this subject by the station, and a number of plants formerly hought to be suitable for pasture are found to be poisonous at certain

stages, including three species of Solidago and several milkweeds. The succulent green tips of the rabbit brush cause heavy losses, and goose grass, not formerly suspected, is found to be very toxic to sheep but not to cattle. The cause of the increasing losses seems to lie in the progressive destruction of palatable forage, forcing the animals to eat plants which a few years ago would seldom if ever have been touched. The station is working out the poisonous doses, habits of the plants, and methods of control. Swell head of sheep appears to be connected with these troubles, and has caused heavy losses at times in certain areas and is apparently due to some plant irritant.

Poisonous-plant studies at the Colorado station have been mainly on the whorled milkweed, from which the toxic principle has been isolated. Spraying with salt solution is an effective means of killing it out.

Reference is made to other investigations along this line under the head of agricultural chemistry.

AGRICULTURAL ENGINEERING AND RURAL ECONOMICS.

The Oregon station has perfected a cheap and practicable method of land clearing, by means of a small oven and pipe, which will consume a large stump, with the roots, in about four days and leave no hole in the ground, at a cost of about $1.20 per stump.

At the Wisconsin station T. N. T. was found to be excellent for clearing land, as it is not affected by moisture up to 5 per cent or by dry cold.

Two forms of silo giving the best results at the Iowa station, which are also not expensive, are the concrete block and concrete stave silo.

Tractors were found by this station to be satisfactory to 90 per cent of those using them, the principal cause of failure being lack of experience. Kerosene was the most generally used fuel, and two and three plow outfits were found best adapted to field work.

A study of methods of storing ice on the farm at the South Dakota station gave a recovery of 47 per cent under the best conditions.

A study of the cost of producing farm products at the Nebraska Station showed that this has risen in about the same proportion as that of manufactured articles. Wages paid farm labor have more than doubled in the last five years. Nearly all farmers receive less per hour for their labor than skilled city laborers.

INSULAR STATIONS.

The Office of Experiment Stations continued to exercise general supervision over the stations in the insular possessions which derive their support from direct Federal appropriation to the Department

of Agriculture. These stations are located in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands. The relations of the office with them are in immediate charge of W. H. Evans. Separate reports are made upon their operations.

VISITATION OF THE STATIONS.

The examination of the work and expenditures of the stations was carried on as in the past, each continental station receiving Federal funds being visited by a representative of the office during the year. This examination was participated in by five members of the office force—the Chief (E. W. Allen), W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte.

In addition to this personal examination on the ground, the office maintains close relations with the stations through correspondence, passes upon and approves the projects conducted under the Adams fund, and at the close of the year examines the financial reports of the stations before they are formally approved.

STATISTICS.

General statistics, 1919.

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in extension work.	Publications during fiscal year 1918–19.		Number of names on mailing list.
								Number.	Pages.	
Alabama (College)	Auburn	J. F. Duggar	Feb. —, 1883	Feb. 24, 1888	26	11	20	11	224	26,000
Alabama (Canebrake)	Uniontown	J. M. Burgess	Jan. 1, 1886							
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		10	9				
Alaska	Sitka	C. C. Georgeson	1898		6			1	96	4,232
Arizona	Tucson	D. W. Working		1889	18	9		8	281	20,000
Arkansas	Fayetteville	Martin Nelson		1887	18	18		52	403	6,359
California	Berkeley	T. F. Hunt	1875	Mar. —, 1888	124	95	71	50	1,411	36,753
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	33	18	6	7	478	9,000
Connecticut (State)	New Haven	E. H. Jenkins	Oct. 1, 1875	May 18, 1887	21	1	6	9	498	9,300
Connecticut (Storrs)	Storrs	do		May 18, 1887	10	5	5	4	171	7,018
Delaware	Newark	Harry Hayward		Feb. 21, 1888	11	6	4	4	114	8,000
Florida	Gainesville	P. H. Rolfs		1888	10	2	1	27	402	17,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	7			29	146	11,000
Guam	Guam	C. W. Edwards	1909		4					2,983
Hawaii	Honolulu	J. M. Westgate	1901		9		8	1	55	5,906
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	29	17	7	11	260	12,475
Illinois	Urbana	Eugene Davenport		Mar. 21, 1888	83	67	35	38	912	42,000
Indiana	Lafayette	C. G. Woodbury	1885	Jan. —, 1888	56	16		31	1,304	26,000
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	74	22		21	998	29,000
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	74	40		12	514	10,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	49	20	7	8	294	20,000
Louisiana (Sugar)	New Orleans		Sept. —, 1885							
Louisiana (State)	Baton Rouge	W. R. Dodson	Apr. —, 1886		21	1	2	2	48	8,330
Louisiana (North)	Calhoun		May —, 1887							
Maine	Orono	C. D. Woods	Mar. —, 1885	Oct. 1, 1887	19			65	374	15,000
Maryland	College Park	H. J. Patterson	1888	Apr. —, 1888	24	12		10	212	16,000
Massachusetts	Amherst	F. W. Morse [1]	1882 [2]	Mar. 2, 1888	42	17		21	497	26,266
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	60	21		20	1,341	45,000
Minnesota	University Farm, St. Paul.	R. W. Thatcher	Mar. 7, 1885	1888	83	61	3	11	551	9,800
Mississippi	Agricultural College	J. R. Ricks		Jan. 27, 1888	19	7	1	8	240	20,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	51	43		147	776	14,613
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		5					
Montana	Bozeman	F. B. Linfield		July 1, 1893	26	13		16	270	12,500
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	34	15	2	10	256	18,304

Nevada	Reno	S. B. Doten		Dec. —, 1887	16	4	1	4	164	4,500
New Hampshire	Durham	J. C. Kendall	1886	Aug. 4, 1887	18	14	16	22	125	22,000
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		30	18	13	121	1,515	9,000
New Jersey (College)	do	do		Apr. 26, 1888	17					
New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	21	16	2	88	291	9,500
New York (State)	Geneva	W. H. Jordan	Mar. —, 1882		38			31	2,159	50,000
New York (Cornell)	Ithaca	A. R. Mann	1879	Apr. —, 1888	45	61	18	18	1,169	2,450
North Carolina	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	51	6		5	281	51,000
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	26	6	11	7	268	5,500
Ohio	Wooster	C. E. Thorne	Apr. 25, 1882	Apr. 2, 1888	64			77	1,650	65,000
Oklahoma	Stillwater	H. G. Knight		Dec. 25, 1890	24	16		8	230	15,241
Oregon	Corvallis	A. B. Cordley		July —, 1888	37	38	14	164	382	2,000
Pennsylvania	State College	R. L. Watts		June 30, 1887	65	52	65	5	110	36,000
Pennsylvania (Nutrition)	do	H. P. Armsby	1907		7					500
Porto Rico	Mayaguez	D. W. May			9		2	3	135	4,160
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	8	2		7	403	2,000
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	19	11	12	4	268	4,300
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	18	14		5	148	24,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	24	6		5	54	11,183
Texas	College Station	B. Youngblood		Apr. 3, 1889	51	3		20	916	38,425
Utah	Logan	F. S. Harris		1890	30	20	7	12	386	8,300
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	14	7	3	4	136	14,000
Virginia	Blacksburg	A. W. Drinkard, jr	1888	1891	26	9		4	182	10,000
Virginia (Truck)	Norfolk	T. C. Johnson			7			4	94	6,500
Virgin Islands	St. Croix	L. Smith			1					
Washington	Pullman	E. C. Johnson		1891	30	11		4	107	8,500
West Virginia	Morgantown	J. L. Coulter		June 11, 1888	28	17	18	9	198	16,000
Wisconsin	Madison	H. L. Russell	1883	1887	84	56	49	14	341	44,200
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	17	11	1	6	208	5,500
Total					1,881	944	410	1,285	25,046	958,598

[1] Acting director.

[2] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch station at the same place.

Revenue and additions

	Station.	Federal.		State.	Balances from previous year.[1]	Fees.	Sales.	Miscellaneous.
		Hatch fund.	Adams fund.					
1	Alabama	$15,000.00	$15,000.00	$27,000.00	$4,715.69		$705.13	$5,294.93
2	Alaska							[2]65,000.00
3	Arizona	15,000.00	15,000.00	34,395.55	2,351.89		25,173.56	
4	Arkansas	15,000.00	15,000.00	40,047.35	3,090.89	$785.30	19,497.03	
5	California[3]	15,000.00	15,000.00	106,803.44		6,097.00	59,851.11	7,786.11
6	Colorado	15,000.00	15,000.00	93,125.40	20,955.47		1,952.49	
7	Connecticut (State).	7,500.00	7,500.00	27,250.00	1,496.50	7,700.00		14,407.39
8	Connecticut (Storrs).	7,500.00	7,500.00	7,500.00	3,267.69			11,990.45
9	Delaware	15,000.00	15,000.00	10,000.00			32,776.45	
10	Florida	15,000.00	15,000.00	9,250.89	4,427.87		5,737.92	
11	Georgia[4]	15,000.00	15,000.00	639.57	3,983.68	18.25	5,046.97	
12	Guam			[5] 3,600.00				[2]20,000.00
13	Hawaii							[2]46,284.91
14	Idaho	15,000.00	15,000.00		993.96		2,287.25	
15	Illinois	15,000.00	15,000.00	195,500.00	68,448.23		93,543.56	
16	Indiana	15,000.00	15,000.00	81,000.00	139,211.38	149,710.85	185,713.01	
17	Iowa	15,000.00	15,000.00	142,193.37	19,715.64		53,947.88	
18	Kansas	15,000.00	15,000.00	59,500.00	21,606.18		54,436.08	
19	Kentucky	15,000.00	15,000.00	50,000.00	47,884.57	120,953.35	74,884.36	1,000.00
20	Louisiana	15,000.00	15,000.00	24,500.00			8,992.94	7,349.04
21	Maine	15,000.00	15,000.00	16,252.85		11,839.25	14,645.28	
22	Maryland	15,000.00	15,000.00	28,118.76	5,856.89		38,562.68	
23	Massachusetts	15,000.00	15,000.00	37,789.82	20,829.91	120.00	16,010.04	6,745.81
24	Michigan	15,000.00	15,000.00	52,350.64		22,145.00	8,183.85	8,328.10
25	Minnesota	15,000.00	15,000.00	205,113.45			100,662.49	517.61
26	Mississippi	15,000.00	15,000.00	34,250.00	6,041.27	90.00	24,148.70	2,329.96
27	Missouri	15,000.00	15,000.00	8,283.89	34,627.32	37,442.06	34,203.39	
28	Montana	15,000.00	15,000.00	99,394.15			13,479.80	
29	Nebraska	15,000.00	15,000.00	60,600.29	89,138.26		81,470.11	
30	Nevada	15,000.00	15,000.00	2,923.47	2,181.43		3,788.93	
31	New Hampshire	15,000.00	15,000.00				1,695.63	11,360.74
32	New Jersey (State)			65,782.86		41,893.95	35,282.70	38.75
33	New Jersey (College).	15,000.00	15,000.00					
34	New Mexico	15,000.00	15,000.00	7,500.00	14,688.91		6,872.83	
35	New York (State)[4,5].	1,500.00	1,500.00	148,160.71	5,137.96			
36	New York (Cornell)[3].	13,500.00	13,500.00					175,000.00
37	North Carolina	15,000.00	15,000.00	109,318.00	1,616.70		7,370.83	
38	North Dakota[4]	15,000.00	15,000.00	66,500.00	17,780.43		48,768.79	6,000.00
39	Ohio	15,000.00	15,000.00	265,530.00	80,521.67		50,140.16	
40	Oklahoma	15,000.00	15,000.00	4,502.31	5,270.57		11,519.94	
41	Oregon	15,000.00	15,000.00	44,933.34	25,225.78		14,570.79	2,000.00
42	Pennsylvania	15,000.00	15,000.00		3,449 13		102,145.21	2,637.30
43	Porto Rico							[2]45,000.00
44	Rhode Island	15,000.00	15,000.00		2,344.43			4,602.47
45	South Carolina	15,000.00	15,000.00		1,009.41		3,926.61	20,629.06
46	South Dakota	15,000.00	15,000.00	15,546.92	8,941.25		3,679.59	11,543.22
47	Tennessee	15,000.00	15,000.00	33,162.55			22,169.23	
48	Texas	15,000.00	15,000.00	195,270.40	3,297.29		61,995.54	
49	Utah	15,000.00	15,000.00	28,485.46	599.66		10,351.20	
50	Vermont	15,000.00	15,000.00	4,150.00				
51	Virgin Islands							[2]15,000.00
52	Virginia	15,000.00	15,000.00	38,250.00	11,944.40		9,148.20	705.38
53	Washington	15,000.00	15,000.00	47,253.65	5,402.46		23,841.90	
54	West Virginia	15,000.00	15,000.00	45,148.00			17,270.25	
55	Wisconsin	15,000.00	15,000.00	157,212.11			47,513.01	
56	Wyoming	15,000.00	15,000.00		603.76		1,854.50	
	Total	720,000.00	720,000.00	2,734,089.20	688,658.53	398,795.01	1,439,817.92	491,551.75

[1] Not including balances from Federal funds.
[2] Including Federal appropriations: Alaska $65,000; Guam $20,000; Hawaii $45,000; Porto Rico $45,000; Virgin Islands $15,000.
[3] The resources from other than the Federal funds are estimated.

to equipment, 1918–19.

Total.	Additions to equipment.							
	Buildings.	Library.	Apparatus.	Farm implements.	Live stock.	Miscellaneous.	Total.	
$67,715.75	$634.35	$417.91	$616.67	$468.45	....	....	$2,137.38	1
65,000.00	4,908.21	....	18.28	1,327.93	$427.50	$160.00	6,841.92	2
91,921.00	10.50	12.21	496.25	1,550.00	600.00	1,000.00	3,668.96	3
93,420.57	300.00	250.00	350.00	375.00	1,200.00	200.00	2,675.00	4
210,538.18	8,012.27	868.94	1,013.58	2,951.90	7,922.44	1,191.14	21,960.27	5
146,033.36	12,996.93	185.77	1,799.09	3,900.37	411.75	1,273.38	20,567.29	6
65,853.89	9.48	598.10	111.20	734.65	....	335.12	1,788.55	7
37,758.14	521.55	14.50	46.25	304.99	281.00	897.80	2,066.09	8
72,776.45	....	175.00	770.03	1,238.18	2,000.00	....	4,183.21	9
49,416.68	....	375.44	526.74	731.66	....	247.43	1,881.27	10
39,688.47	....	47.24	1,209.37	1,340.96	1,500.00	....	4,097.57	11
20,000.00	....	....	....	....	....	....	....	12
49,884.91	....	....	....	....	....	....	....	13
33,281.21	8,000.00	100.00	1,000.00	3,000.00	4,000.00	3,500.00	19,600.00	14
387,491.79	2,890.74	....	4,997.01	....	17,671.63	....	25,559.38	15
585,635.24	109,700.00	1,400.00	4,200.00	10,000.00	8,000.00	3,500.00	136,800.00	16
245,856.89	....	....	2,980.35	1,447.21	2,103.00	....	6,530.56	17
165,542.26	2,000.00	100.00	1,500.00	4,000.00	9,009.50	....	16,609.50	18
324,722.28	5,751.24	344.10	2,312.64	598.94	7,159.70	14,885.79	31,052.41	19
70,841.98	1,482.32	425.78	220.28	371.61	1,599.30	260.35	4,359.64	20
72,737.38	....	400.00	200.00	800.00	1,150.00	....	2,550.00	21
102,538.33	....	277.11	1,684.06	4,196.63	67.00	1,242.12	7,466.92	22
111,495.58	1,502.91	426.47	829.32	390.68	132.00	....	3,281.38	23
121,007.59	12,260.00	640.00	1,273.00	2,555.00	826.00	692.00	18,247.00	24
336,293.55	16,630.00	1,328.00	1,288.00	3,265.00	14,750.00	3,778.00	41,039.00	25
96,859.93	3,266.56	41.25	....	1,792.17	6,247.28	1,770.58	13,117.84	26
144,556.66	2,953.36	37.96	2,032.17	5,484.13	11,927.41	1,069.85	23,504.88	27
142,873.95	10,235.00	581.00	1,854.00	2,332.00	2,132.00	2,696.00	19,830.00	28
261,208.66	105,000.00	1,050.00	564.30	2,527.81	27,067.87	100,000.00	236,209.98	29
38,893.83	3,000.00	60.00	379.64	75.00	....	....	3,514.64	30
43,056.37	....	116.00	649.19	475.85	22.50	....	1,263.54	31
142,998.26	....	....	....	....	....	....	....	32
30,000.00	2,000.00	260.00	2,500.00	2,300.00	40.00	1,400.00	8,500.00	33
59,061.74	1,041.43	18.30	470.20	887.19	3,535.00	162.90	6,115.02	34
156,298.67	....	....	....	....	....	....	....	35
202,000.00	5,200.00	983.47	2,198.85	168.95	646.12	1,000.00	10,197.39	36
148,305.53	2,500.00	500.00	200.00	400.00	375.00	....	3,975.00	37
169,049.22	....	30.00	912.00	175.00	2,260.00	350.00	3,727.00	38
426,191.83	14,007.69	1,063.28	3,244.20	1,593.46	1,772.17	4,692.52	26,373.32	39
51,292.82	685.33	478.04	200.55	1,146.99	782.28	395.60	3,688.79	40
116,729.91	664.35	37.55	485.29	....	3,186.42	1,324.52	5,698.13	41
138,231.64	....	922.80	300.00	388.45	18,401.35	....	20,012.60	42
45,000.00	4,552.91	84.70	227.75	806.11	674.60	786.20	7,132.27	43
36,946.90	675.00	180.00	80.00	155.00	130.00	130.00	1,350.00	44
55,565.08	800.00	300.00	900.00	200.00	600.00	....	2,800.00	45
69,710.98	....	27.27	278.69	341.23	200.00	198.97	1,046.16	46
85,331.78	47,394.37	279.33	639.13	8,261.67	6,500.00	641.89	63,716.39	47
290,563.23	14,009.18	1,750.00	3,774.51	6,915.11	2,069.10	2,571.52	31,089.42	48
69,436.32	926.59	404.92	1,297.50	4,502.35	128.97	1,260.87	8,521.20	49
34,150.00	1,147.04	19.98	382.38	37.77	350.30	....	1,937.47	50
15,000 00	1,497.13	....	1,110.87	2,702.91	28.00	613.67	5,952.58	51
90,047.98	1,512.99	189.53	110.52	1,249.77	5,452.65	....	8,515.46	52
106,498.01	3,690.99	179.18	2,403.73	2,003.24	184.00	....	8,461.14	53
92,418.25	10,000.00	700.00	3,000.00	2,400.00	2,700.00	400.00	19,200.00	54
234,725.12	5,095.16	794.46	3,285.36	6,473.72	4,661.30	2,168.32	22,478.32	55
32,458.26	4,228.68	250.00	624.31	821.26	1,761.67	250.00	7,935.92	56
7,192,912.41	433,694.26	19,726.59	63,547.26	102,166.30	184,646.81	157,046.54	960,827.76	

[4] Including balances from previous year: Georgia $4,388.12 Hatch, $9,267.80 Adams; New York (State) 47.81 Hatch, $245.12 Adams; North Dakota $276.08 Hatch, $361.15 Adams.

[5] Territorial.

[6] For unexpended balances in 1918–19 see tables immediately following.

Expenditures from United States appropriation received under the

Station.	Amount of appropriation.	Classified expenditures.						
		Salaries.	Labor.	Publications.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.
Alabama	$15,000.00	$7,740.19	$3,085.72	$899.72	$202.33	$218.08	$313.82	$79.84
Arizona	15,000.00	11,758.62		75.40	458.92	71.52	725.91	213.73
Arkansas	15,000.00	7,835.92	1,600.39	2,474.72	483.49	240.77	128.00	222.79
California	15,000.00	12,952.12	840.00	1,187.88				
Colorado	15,000.00	9,402.98	1,466.40	1,792.49	57.19	60.04		69.77
Connecticut:								
State	7,500.00	7,086.80	413.20					
Storrs	7,500.00	6,107.02	1,057.44		20.80	12.97	.50	
Delaware	15,000.00	9,551.94	1,274.61	898.30	497.57	130.95		550.14
Florida	15,000.00	6,201.65	3,409.22	2,250.39	554.59	93.35	211.68	3.75
Georgia	[1] 15,000.00	6,608.03	2,405.80	1,651.15	470.76	241.19	352.62	
Idaho	15,000.00	9,217.11	2,145.16	309.00	227.32	52.77	52.40	201.80
Illinois	15,000.00	13,764.92	185.85	914.70	60.05			12.50
Indiana	15,000.00	10,962.08	1,414.30	7.00	44.70			79.10
Iowa	15,000.00	7,564.05	1,158.49	1,416.84	323.95	187.96	236.34	32.54
Kansas	15,000.00	9,191.67	4,504.58		186.83	13.66		249.53
Kentucky	15,000.00	13,975.02	121.14	26.95	18.25		781.85	
Louisiana	15,000.00	7,664.62	3,825.73	268.38	155.95	108.06	2.40	.75
Maine	15,000.00	6,851.45	2,168.67	125.38	683.31	149.22	566.83	
Maryland	15,000.00	11,173.32	2,653.30	418.69	21.67			44.74
Massachusetts	15,000.00	13,631.68	915.26	80 50				20.59
Michigan	15,000.00	11,473.65	1,216.07	119.81	145.09	5.00	147.15	202.16
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	8,175.81	2,081.22		101.61	99.88	93.57	
Missouri	15,000.00	10,019.20	1,905.33		208.93	331.94	42.85	117.84
Montana	15,000.00	10,572.19	1,956.77	339.20	503.35	95.36	29.21	34.12
Nebraska	15,000.00	6,453.33	4,034.01	1,395.84				323.32
Nevada	15,000.00	9,839.80	1,969.07	690.71	151.58	22.07	162.52	93.05
New Hampshire	15,000.00	8,532.35	898.95	2,071.71	901.82	350.78	600.00	22.71
New Jersey	15,000.00	8,852.78	750.51	937.06	480.86	34.94		461.31
New Mexico	15,000.00	4,519.92	3,548.40	1,121.79	87.02	80.97	69.73	124.96
New York:								
State	[1] 1,500.00	466.58	660.32		62.90	78.44		
Cornell	13,500.00	6,481.66	2,834.98		119.67	76.46		912.19
North Carolina	15,000.00	6,735.56	2,888.79	895.97	136.91	48.99	168.45	54.77
North Dakota	[1] 15,000.00	11,814.65	2,022.79	16.05	1 .31			33.00
Ohio	15,000.00	5,902.80	53.60	1,032.38	289.69	681.25	180.62	359.92
Oklahoma	15,000.00	8,911.83	1,854.54	758.00	104.34	11.41	163.40	107.99
Oregon	15,000.00	9,843.26	1,772.37	1,305.76	139.62	108.26	21.00	78.33
Pennsylvania	15,000.00	9,400.00	2,316.44	1,875.65	6.18	153.09		
Rhode Island	15,000.00	6,070.00	3,414.66	1,966.45	181.25	151.87	490.57	
South Carolina	15,000.00	6,400.35	3,416.72	622.21	587.12	145.31	86.07	
South Dakota	15,000.00	8,511.64	1,699.29	2,411.59	596.49	39.31		113.01
Tennessee	15,000.00	11,195.00	1,316.31	233.54	328.16	38.90	421.76	16.25
Texas	15,000.00	8,623.41	1,706.20	377.34	557.80	247.42	178.60	343.87
Utah	15,000.00	7,564.00	2,712.24	20.19	566.46	82.40	42.56	33.22
Vermont	15,000.00	7,603.61	1,590.33	773.27	343.87	201.84	1,379.49	235.82
Virginia	15,000.00	9,273.15	2,820.35	383.08	345.61	127.84	85.82	72.95
Washington	15,000.00	8,482.46	3,478.94	698.80	247.41		7.25	179.25
West Virginia	15,000.00	10,210.67	2,252.74	1,045.10	19.22			5.71
Wisconsin	15,000.00	10,717.50	628.00	150.15	84.71	5.40	26.66	826.67
Wyoming	15,000.00	7,759.17	2,509.38	1,062.47	36.84	52.66	279.18	195.01
Total	720,000.00	444,647.52	94,923.58	37,101.61	11,821.50	4,852.33	8,048.81	6,729.00

[1] Including balances as follows: Georgia, $4,388.12; New York (State), $47.81; North Dakota, $276.08.

ct of Mar. 2, 1887 (Hatch Act), for the year ended June 30, 1919.

Classified expenditures—Continued.

Seeds, plants, and sundry supplies.	Fertilizers.	Feeding stuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Buildings and repairs.	Balances.
$281.33	$274.55	$678.59	$408.20	$247.92	$60.00	$114.29	....	$137.26	$20.00	$238.16	......
110.24	38.28	....	12.21	112.56	188.21	207.25	....	1,027.15	......	....	......
397.80	106.54	127.97	....	610.78	241.03	57.34	....	341.84	20.00	110.62	......
....	....	....	....	....	....	....	....	....	20.00	....	......
205.23	.57	34.86	98.76	....	209.73	485.07	$186.00	910.91	20.00	....	......
....	....	....	....	....	....	....	....	....	......	....	......
155.83	....	22.50	....	55.80	4.50	....	....	42.64	20.00	....	......
435.58	360.38	39.40	142.69	374.64	263.60	183.50	....	268.90	27.80	....	......
183.34	44.64	1,265.97	316.20	279.33	5.89	4.03	....	118.97	20.00	37.00	......
409.37	570.52	256.40	5.25	569.19	269.73	15.78	356.00	232.72	108.93	476.56	......
313.47	15.00	1,481.60	....	148.90	14.60	109.93	....	475.94	20.00	215.00	......
....	....	....	....	.50	....	....	....	41.48	20.00	....	......
178.63	20.00	1,655.95	3.98	81.39	....	62.70	....	488.77	......	1.40	......
980.46	62.90	2,249.74	....	126.02	8.15	....	335.00	235.46	......	82.10	......
261.50	....	119.15	3.25	134.00	51.60	117.00	....	164.43	......	2.80	......
6.04	....	....	50.75	....	....	....	....	....	20.00	....	......
42.50	291.75	1,155.00	314.75	12.70	3.00	166.70	589.40	132.72	......	265.59	......
475.52	924.20	1,155.01	249.53	384.56	45.28	....	235.00	409.50	20.00	556.54	......
110.87	....	....	27.11	9.72	320.70	215.08	....	....	4.80	....	......
....	203.65	6.30	....	....	1.20	120.82	....	....	20.00	....	......
262.12	45.00	....	537.80	181.62	.90	11.29	....	632.34	20.00	....	......
....	....	....	....	....	....	....	....	....	......	....	......
38.00	....	2,616.37	....	35.53	106.65	....	1,651.36	....	......	....	......
239.22	8.50	1,838.90	....	62.29	53.29	5.26	69.20	27.64	......	69.61	......
504.43	....	348.23	64.81	24.20	43.75	276.60	50.00	188.78	......	....	......
72.23	....	1,887.63	8.45	554.18	156.85	114.16	....	....	......	....	......
155.63	....	796.00	40.45	76.09	162.05	....	280.00	395.18	......	165 80	......
459.89	150.19	86.17	116.80	214.65	17.40	19.70	7.50	508.86	20.00	20.52	......
348.72	51.70	....	19.56	9.94	417.71	28.80	....	2,102.82	7.90	495.39	......
346.05	59.17	2,191.50	18.30	357.52	102.27	65.16	1,770.00	278.55	21.95	236.74	......
68.93	....	....	....	53.03	....	2.74	....	9.22	......	85.03	$11.81
489.06	232.30	....	16.57	727.57	353.65	351.40	....	231.62	......	672.87	......
689.01	731.70	1,097.36	....	371.75	....	115.00	129.00	166.74	20.00	750.00	......
501.98	71.17	....	....	183.73	194.85	72.00	....	48.80	22.67	....	......
,167.63	470.70	1,943.96	....	2,206.10	6.50	175.91	....	40.23	20.00	468.71	......
591.38	....	1,407.27	69.39	174.78	325.00	44.89	12.50	210.45	20.00	232.83	......
618.03	29.47	418.07	....	36.40	33.00	....	....	576.38	20.00	....	......
270.40	320.35	99.90	213.14	83.50	....	....	....	254.78	......	6.57	......
356.58	1,455.79	270.19	197.29	149.92	5.25	6.35	44.00	7.10	20.00	212.73	......
410.77	886.84	1,190.75	100.97	268.80	389.13	142.13	....	251.85	20.00	80.98	......
262.19	....	643.37	9.00	290.45	109.50	151.72	....	51.96	53.20	57.28	......
460.06	....	513.13	95.02	243.80	45.96	....	....	71.01	20.00	1.10	......
275.10	302.85	19.00	42.79	725.54	753.38	85.67	....	179.18	20.00	561.85	......
947.17	70.00	971.34	279.50	443.59	145.91	39.44	41.47	913.54	20.00	106.97	......
,092.22	6.63	607.94	17.00	42.80	73.15	68.46	43.30	292.31	20.00	607.96	......
516.04	306.13	74.00	176.98	340.52	126.00	....	3.00	231.46	40.00	77.07	......
527.61	21.00	67.85	15.00	267.39	85.94	636.96	....	252.14	20.00	12.00	......
324.00	269.79	49.00	....	15.89	2.00	....	....	805.88	......	....	......
552.86	233.89	59.90	....	121.13	....	880.70	12.00	700.43	......	....	......
341.54	....	1,685.79	129.00	73.76	....	263.45	....	19.15	......	592.60	......
7,436.61	8,636.15	31,132.06	3,800.50	11,484.48	5,397.31	5,417.28	5,814.73	14,477.09	767.25	7,500.38	11.81

Expenditures from United States appropriation received under the

Station.	Amount of appropriation.	Classified expenditures.						
		Salaries.	Labor.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.	Seeds, plants, and sundry supplies.
Alabama	$15,000.00	$10,457.60	$1,193.01	$89.45	$317.70	$233.07	$447.95	$205.49
Arizona	15,000.00	11,737.76	1,104.81	102.85	53.22	13.75	127.91	281.20
Arkansas	15,000.00	10,632.58	1,368.79	121.85	173.49	249.72	348.12	528.28
California	15,000.00	8,754.04	1,270.05	24.83	.10	10.78	1,576.85	407.62
Colorado	15,000.00	13,133.55	522.68	13.21	29.09	3.00	322.06	110.57
Connecticut:								
State	7,500.00	5,730.37	110.43	50.00	85.09	497.32	305.72	198.42
Storrs	7,500.00	5,655.95	1,046.88	24.86	.86		112.52	63.89
Delaware	15,000.00	11,395.50	1,176.30	25.16	23.34		1,290.57	215.13
Florida	15,000.00	10,012.31	1,115.28	108.53	241.31	67.57	779.18	367.75
Georgia	[1] 15,000.00	6,916.63	816.77	73.10	266.63	339.43	794.74	708.99
Idaho	15,000.00	9,594.27	2,137.59	32.23	168.07	68.90	583.43	354.11
Illinois	15,000.00	12,820.02	1,153.38	32.60	9.53		263.31	
Indiana	15,000.00	9,993.35	394.02	63.57	1.33		553.09	282.92
Iowa	15,000.00	7,152.40	2,752.33	313.04	81.83	136.02	763.17	1,063.41
Kansas	15,000.00	7,916.42	3,400.77	33.59	89.92	27.67	512.47	423.28
Kentucky	15,000.00	12,183.42	417.70	33.00	45.04	135.61	187.18	148.03
Louisiana	15,000.00	11,208.58	509.00	100.81	61.68	644.89	1,022.66	258.51
Maine	15,000.00	9,726.27	1,973.28	126.52	82.31	299.35	10.50	287.06
Maryland	15,000.00	10,948.31	230.83	21.70			942.77	162.46
Massachusetts	15,000.00	13,088.31	687.01				225.38	129.55
Michigan	15,000.00	12,037.75	1,553.12	2.80	37.88		35.49	39.89
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	7,470.69	6,147.03	56.01	40.01	231.39		210.31
Missouri	15,000.00	7,302.29	2,247.79	7.04	383.41	38.22	730.14	398.61
Montana	15,000.00	11,891.50	1,016.97	45.98	48.87	29.09	429.15	260.05
Nebraska	15,000.00	9,328.21	2,119.57	40.94	205.24		202.48	534.72
Nevada	15,000.00	9,483.33	2,485.42	71.37	120.09	15.05	151.41	189.27
New Hampshire	15,000.00	9,635.02	1,981.94	26.58	6.13		154.69	442.65
New Jersey	15,000.00	12,482.56	773.44	36.16	2.00	596.08	318.17	143.48
Mew Mexico	15,000.00	8,350.78	2,661.94	48.68	35.60	278.34	654.02	273.94
New York:								
State	[1] 1,500.00	1,459.50					38.00	
Cornell	13,500.00	12,004.85	913.17	25.53			272.61	129.81
North Carolina	15,000.00	12,659.07	896.15	93.85	7.13	84.25	127.87	204.22
North Dakota	[1] 15,000.00	9,695.04	772.46	42.44			628.06	204.89
Ohio	15,000.00	7,724.83					1,486.80	
Oklahoma	15,000.00	10,429.46	1,889.92	9.17	1.28	13.45	151.03	210.40
Oregon	15,000.00	13,559.41	219.92		48.46		552.01	105.52
Pennsylvania	15,000.00	11,870.35	26.53	8.78	76.94	23.55	733.42	43.84
Rhode Island	15,000.00	8,368.24	3,300.05	122.43	30.59	333.64	167.86	101.75
South Carolina	15,000.00	10,292.88	1,909.46	40.31	31.20	261.82	596.96	283.72
South Dakota	15,000.00	9,396.61	2,732.85	24.47	180.50		229.99	357.71
Tennessee	15,000.00	11,597.66	872.05	57.64	28.29	250.09	707.52	64.10
Texas	15,000.00	10,560.08	1,445.90	101.19	236.08	234.79	758.33	182.31
Utah	15,000.00	7,255.71	4,335.31	16.38	169.88	115.98	1,037.01	308.35
Vermont	15,000.00	8,000.11	2,795.66	29.95	74.90	27.37	264.87	248.18
Virginia	15,000.00	9,980.00	2,809.64	2.23	26.04	9.90	238.30	255.20
Washington	15,000.00	11,433.04	2,134.88	63.37	10.34		309.96	272.78
West Virginia	15,000.00	9,954.55	1,030.44		3.19		472.69	685.37
Wisconsin	15,000.00	9,013.00	3,039.76	22.26	5.52	38.95	327.02	335.31
Wyoming	15,000.00	9,177.93	1,632.58	12.27	42.60	118.80	651.49	129.26
Total	720,000.00	496,472.09	77,124.86	2,399.73	3,582.71	5,427.84	23,596.93	12,812.31

[1] Including balances as follows: Georgia, $9,267.80; New York (State), $245.12; North Dakota, $361.15.

ct of Mar. 16, 1906 (Adams Act), for the year ended June 30, 1919.

Classified expenditures—Continued.

Fertilizers.	Feeding stuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Buildings and repairs.	Balances.
$158.98	$740.02	$9.31	$187.26	$15.75	$422.58	....	$466.43	....	$55.40	......
....	....	....	108.41	.75	161.85	....	1,112.20	....	195.29	......
98.10	386.00	....	207.23	11.90	300.50	$20.50	549.44	....	3.50	......
....	85.55	12.50	47.05	39.47	593.34	950.70	1,055.69	....	171.43	......
2.96	4.38	4.50	100.85	2.45	258.58	23.50	468.62	....	....	......
78.43	346.07	....	....	5.40	....	....	92.75	....	....	......
3.50	241.25	....	.90	....	....	138.67	210.72	....	....	......
....	....	19.34	....	....	586.53	....	145.40	....	122.73	......
109.99	....	53.74	285.94	196.54	287.06	....	1,309.94	....	64.86	......
741.09	504.95	41.97	671.77	124.63	1,193.59	1,569.75	11.30	....	224.66	......
....	121.40	13.00	278.09	148.95	728.80	....	531.00	....	240.16	......
....	494.63	....	91.23	26.46	....	15.00	93.84	....	....	......
....	25.99	52.30	479.79	258.15	1,234.29	1,286.73	239.13	....	135.34	......
27.61	1,609.41	....	163.40	170.18	355.17	....	92.38	....	319.65	......
....	1,126.63	....	135.63	53.81	336.15	622.88	142.17	....	178.61	......
....	766.62	15.61	266.43	....	113.72	684.50	3.14	....	....	......
....	239.15	99.00	....	223.25	53.58	....	578.89	....	....	......
....	1,810.54	110.30	107.74	....	10.03	....	352.13	$60.00	43.97	......
....	....	....	584.97	570.20	1,376.38	....	91.22	6.60	64.56	......
115.20	201.25	....	....	....	553.30	....	....	....	....	......
3.00	682.19	....	19.52	1.90	36.10	56.50	6.65	....	487.21	......
....	....	....	....	....	....	....	....	....	....	......
....	459.75	10.75	201.68	....	....	....	172.38	....	....	......
....	1,418.56	....	275.33	868.25	532.55	352.50	15.72	....	429.59	......
....	....	36.33	122.14	125.50	624.31	....	370.11	....	....	......
....	1,191.04	....	317.30	20.64	215.28	611.47	186.73	....	26.38	......
....	1,072.41	2.50	33.73	3.00	44.67	678.00	635.20	....	14.55	......
267.50	965.64	....	261.20	18.48	629.49	15.00	174.54	....	421.14	......
3.13	360.00	....	62.72	21.85	131.49	....	24.70	....	44.22	......
27.60	335.24	....	492.07	57.63	269.97	800.00	....	....	714.19	......
....	....	....	....	....	....	....	....	....	....	$2.50
6.10	....	....	69.16	4.00	74.77	....	....	....	....	......
279.25	9.00	....	115.50	....	107.04	250.00	166.67	....	....	......
....	1,339.86	5.10	554.29	69.00	440.46	995.36	80.45	....	172.59	......
....	1,507.40	....	685.87	300.00	3,000.34	....	....	....	294.76	......
....	424.10	44.68	297.21	9.07	152.56	769.78	188.39	....	409.50	......
....	....	....	19.95	14.50	477.73	....	2.50	....	....	......
....	358.00	10.00	46.06	31.16	1,537.48	....	233.89	....	....	......
44.00	1,703.10	6.80	298.67	134.37	40.30	133.84	....	8.11	206.25	......
252.89	....	39.20	33.74	152.72	968.77	....	62.12	....	74.21	......
68.80	294.69	29.34	99.93	258.80	176.57	430.00	667.64	....	52.10	......
18.00	....	75.53	284.64	154.90	354.70	....	205.13	....	329.75	......
....	119.95	10.00	312.16	286.40	438.38	80.00	78.63	....	155.80	......
....	200.20	....	176.80	214.14	784.20	....	322.36	....	63.68	......
18.00	1,838.05	2.98	20.27	....	557.74	307.00	199.94	....	614.98	......
456.06	726.75	....	27.64	9.10	84.15	....	220.09	....	153.90	......
8.23	6.50	....	109.62	....	329.33	9.00	312.95	....	....	......
396.84	184.10	....	316.04	813.90	682.79	....	460.09	....	....	......
....	1,709.44	....	64.94	....	407.95	....	35.85	....	....	......
....	1,685.20	22.15	223.24	8.35	343.74	632.50	92.69	....	227.20	......
3,185.26	27,295.01	726.93	9,258.11	5,425.55	22,008.31	11,433.18	12,461.81	74.71	6,712.16	2.50

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved Mar. 2, 1887, and Mar. 16, 1906.

State or Territory.	Hatch Act.		Adams Act.	
	1888–1918	1919	1906–1918	1919
Alabama	$463,956.42	$15,000.00	$161,619.89	$15,000.00
Arizona	429,803.10	15,000.00	164,955.61	15,000.00
Arkansas	463,139.12	15,000.00	164,900.00	15,000.00
California	465,000.00	15,000.00	164,926.84	15,000.00
Colorado	464,718.82	15,000.00	163,638.93	15,000.00
Connecticut	465,000.00	15,000.00	165,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	463,382.87	15,000.00	160,475.12	15,000.00
Florida	464,966.06	15,000.00	164,996.06	15,000.00
Georgia	464,981.55	10,611.88	161,360.67	5,732.20
Idaho	389,824.13	15,000.00	160,842.22	15,000.00
Illinois	464,564.95	15,000.00	164,851.62	15,000.00
Indiana	464,901.19	15,000.00	165,000.00	15,000.00
Iowa	465,000.00	15,000.00	165,000.00	15,000.00
Kansas	464,995.00	15,000.00	165,000.00	15,000.00
Kentucky	464,996.57	15,000.00	165,000.00	15,000.00
Louisiana	465,000.00	15,000.00	165,000.00	15,000.00
Maine	464,999.62	15,000.00	165,000.00	15,000.00
Maryland	464,967.40	15,000.00	164,236.48	15,000.00
Massachusetts	464,617.70	15,000.00	165,000.00	15,000.00
Michigan	464,676.10	15,000.00	161,341.20	15,000.00
Minnesota	464,917.78	15,000.00	164,345.00	15,000.00
Mississippi	465,000.00	15,000.00	165,000.00	15,000.00
Missouri	460,097.24	15,000.00	164,999.90	15,000.00
Montana	375,000.00	15,000.00	162,417.04	15,000.00
Nebraska	464,932.16	15,000.00	165,000.00	15,000.00
Nevada	464,214.32	15,000.00	163,180.28	15,000.00
New Hampshire	465,000.00	15,000.00	165,000.00	15,000.00
New Jersey	464,949.97	15,000.00	164,558.78	15,000.00
New Mexico	429,509.05	15,000.00	165,000.00	15,000.00
New York	464,825.56	14,952.19	164,745.65	14,754.88
North Carolina	465,000.00	15,000.00	165,000.00	15,000.00
North Dakota	406,778.34	14,723.92	165,000.00	14,638.85
Ohio	465,000.00	15,000.00	163,514.02	15,000.00
Oklahoma	389,568.96	15,000.00	146,360.56	15,000.00
Oregon	450,156.64	15,000.00	160,000.00	15,000.00
Pennsylvania	464,967.43	15,000.00	164,995.41	15,000.00
Rhode Island	465,000.00	15,000.00	162,464.20	15,000.00
South Carolina	464,542.15	15,000.00	163,460.12	15,000.00
South Dakota	408,250.00	15,000.00	160,000.00	15,000.00
Tennessee	465,000.00	15,000.00	165,000.00	15,000.00
Texas	465,000.00	15,000.00	162,592.26	15,000.00
Utah	330,000.00	15,000.00	164,821.94	15,000.00
Vermont	465,000.00	15,000.00	165,000.00	15,000.00
Virginia	462,824.12	15,000.00	164,949.01	15,000.00
Washington	402,102.65	15,000.00	161,080.11	15,000.00
West Virginia	464,968.71	15,000.00	162,859.12	15,000.00
Wisconsin	465,000.00	15,000.00	165,000.00	15,000.00
Wyoming	450,000.00	15,000.00	165,000.00	15,000.00
Total	21,707,345.68	715,287.99	7,849,488.04	710,125.93

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U. S. DEPARTMENT OF AGRICULTURE

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1920

PREPARED BY THE
OFFICE OF EXPERIMENT STATIONS
STATES RELATIONS SERVICE

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1922

STATES RELATIONS SERVICE.

A. C. TRUE, Director.

OFFICE OF EXPERIMENT STATIONS.

E. W. ALLEN, Chief.

RELATIONS WITH INSTITUTIONS FOR AGRICULTURAL RESEARCH.

Supervision of Work and Expenditures of the State Experiment Stations Under Federal Appropriations.

E. W. ALLEN, E. R. FLINT, J. I. SCHULTE, W. H. EVANS, W. H. BEAL.

Experiment Station Record.

E. W. ALLEN, Ph. D., editor; H. L. KNIGHT, B. S., associate editor; SYBIL L. SMITH, M. A., agricultural chemistry and agrotechny; W. H. BEAL, A. B., M. E., and R. W. TRULLINGER, B. S. C. E., meteorology, soils, and fertilizers; W. H. EVANS, Ph. D., and W. E. BOYD, Ph. B., agricultural botany, bacteriology, and plant pathology; H. M. STEECE, B. S., field crops; J. W. WELLINGTON, B. S., horticulture and forestry; W. A. HOOKER, B. S., D. V. M., economic zoology and entomology; C. F. LANGWORTHY, Ph. D., D. Sc., and SYBIL L. SMITH, M. A., foods and human nutrition; F. J. KELLEY, B. S., animal husbandry, dairying, and dairy farming; W. A. HOOKER, B. S., D. V. M., and SYBIL L. SMITH, M. A., veterinary medicine; R. W. TRULLINGER, B. S. C. E., rural engineering; EUGENE MERRITT, A. B., and LOUISE MARBUT, A. B., rural economics; F. H. SHINN, A. B., B. S., and MARIE T. SPETHMANN, agricultural education; MARTHA C. GUNDLACH, A. B., indexing; WILLIAM HENRY, proof reading.

DIVISION OF INSULAR STATIONS.

W. H. EVANS, Ph. D., Chief.

Alaska Experiment Stations.

C. C. GEORGESON, M. S., D. Sc., agronomist in charge, Sitka; M. D. SNODGRASS, B. S., assistant in charge, Fairbanks; G. W. GASSER, B. S., assistant in charge, Rampart; F. E. RADER, B. S., assistant in charge, Matanuska; M. T. WHITE, B. S., assistant in charge, Kodiak.

Guam Experiment Station.

C. W. EDWARDS, B. S., animal husbandman in charge, Island of Guam; GLEN BRIGGS, B. S., agronomist and horticulturist; W. J. GREENE, B. S., assistant in agronomy and extension work; J. GUERRERO, assistant in horticulture; PETER NELSON, assistant.

Hawaii Experiment Station.

J. M. WESTGATE, M. S., agronomist in charge, Honolulu; W. T. POPE, M. S., horticulturist; WALLACE MACFARLANE, specialist in soil investigations; F. G. KRAUSS, superintendent of extenison work, Haiku; R. A. GOFF, B. S., extension agent, Hilo; C. W. CARPENTER, M. S., plant pathologist; H. L. CHUNG, M. S., agronomist; J. C. RIPPERTON, assistant chemist.

Porto Rico Experiment Station.

D. W. MAY, M. Agr., agronomist in charge, Mayaguez; T. B. MCCLELLAND, A. B., horticulturist; W. V. TOWER, B. S., entomologist; L. G. WILLIS, B. S., chemist; THOMAS BREGGER, B. S., plant breeder; J. O. CARRERO, B. S. Ch. E., assistant chemist; W. P. SNYDER, B. S., assistant in plant breeding; H. C. HENRICKSEN, B. Agr., specialist in farm management, San Juan; J. A. SALDANA, assistant in horticulture.

Virgin Islands Experiment Station.

LONGFIELD SMITH, Ph. D., agronomist in charge, St. Croix; C. E. WILSON, M. A., entomologist.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
States Relations Service,
Washington, D. C., March 20, 1922.

Sir: I have the honor to transmit herewith a report on the agricultural experiment stations in the United States for the fiscal year ended June 30, 1920. This is a part of a report prepared in accordance with the following provision of the act of Congress of March 4, 1915, entitled "An act making appropriations for the Department of Agriculture for the fiscal year ending June thirtieth, nineteen hundred and sixteen":

That hereafter there be prepared by the Department of Agriculture an annual report on the work and expenditures of the agricultural experiment stations established under the act of Congress of March second, eighteen hundred and eighty-seven (Twenty-fourth Statutes at Large, page four hundred and forty), on the work and expenditures of the Department of Agriculture in connection therewith, and on the cooperative agricultural extension work and expenditures of the Department of Agriculture and of agricultural colleges under the act of May eighth, nineteen hundred and fourteen, entitled "An act to provide for cooperative agricultural extension work between the agricultural colleges in the several States receiving the benefits of an act of Congress approved July second, eighteen hundred and sixty-two, and of acts supplementary thereto, and the United States Department of Agriculture"; and that there be printed annually eight thousand copies of said report, of which one thousand copies shall be for the use of the Senate, two thousand copies for the use of the House of Representatives, and five thousand copies for the use of the Department of Agriculture (38 Stat. L., p. 1110).

This report embodies the information heretofore submitted in compliance with the provisions of 34 Statutes at Large, page 64, section 5.

Very respectfully,

A. C. True, *Director.*

Hon. Henry C. Wallace,
Secretary of Agriculture.

CONTENTS.

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1920.

By E. W. Allen, E. R. Flint, and J. I. Schulte.

GENERAL CONDITIONS.

The year 1920 brought little relief to the agricultural experiment stations. It continued to be a critical period for them in attempting to maintain their activities under unusual costs on a pre-war revenue. They are the last branch to recover from the effects of the war period.

While the total income of the stations showed a small aggregate increase, its purchasing power fell off very materially. In many cases there was no increase in State support, and in a few instances there was an actual decrease. The result was a serious curtailment of the lines of investigation, and inability to take up many questions upon which there is demand for information.

The demands for scientifically trained men in commercial lines and the better salaries which such opportunities offer has alarmingly depleted the station staff in many cases, and these vacancies have been difficult to fill, owing to the lack of men specially trained for such service. Station salaries, in many instances, have not paralleled salaries of heads of departments in the colleges and universities with which the stations are connected, which discrimination has proved a source of dissatisfaction. The lack of funds and men has affected the colleges as well as the stations, resulting in a tendency to utilize more and more the station force for teaching purposes to the detriment of the investigational work. In some instances not only are members of the station staff called upon to teach, but they have taken considerable part in extension activities.

With decreased purchasing power of the funds available, it has become difficult not only to purchase necessary new apparatus, equipment, and live stock, but in some cases the replacement and prevention of deterioration of the present equipment has become a serious problem. Many of the stations, with the increasing demands for information, are finding themselves restricted for land, a condition which is aggravated by the fact that real estate in the vicinity of such institutions has risen very much in price and is now difficult or impossible to obtain.

To some extent these factors are a part of the very general conditions which have affected the country as a whole as a result of the war, and as these assume a more normal state will probably be more or less corrected. In fact the indications are that the most critical stage has been passed, but the position in which the stations now find themselves calls not only for most careful administration, but for sympathetic understanding and appreciation on the part of those responsible for the general policy of development.

From the nature of the work, the station has, in a measure, been overshadowed in the popular mind by those activities which come into more personal contact with the farmer and the general public; and unless means are devised for giving greater publicity to the importance of the station and its adequate support, the present serious condition may be slow in being properly remedied. Research is basic to success in teaching and extension, and continued neglect of it, while drawing on the results of the past, will soon make itself felt in the other lines of effort. Indeed, this is already the case to some extent.

STATION FUNDS.

The income of the stations for the year (excluding the insular stations) was derived from the Federal appropriations under the Hatch and Adams Acts amounting to $1,440,000, and State appropriations of about $3,500,000, not including sales funds, balances, specific appropriations for regulatory functions, etc. The details of the receipts and expenditures of the several stations are given on pages 88–94.

A brief summary of the resources of the stations, in addition to the Hatch and Adams funds, is given here.

The Alabama Legislature appropriated $5,000 for the station at Auburn, this being the first time in its history that it has received State aid. The local experiment fund of $27,000 was continued. The total State appropriation for the Arizona station was about $73,171, most of it for specific purposes, with sales of $25,377. The State aid for the Arkansas station was approximately $18,896, the sales being $7,500.

The California station received $150,000, or about one-fourth of the appropriation to the college of agriculture, and in addition a special appropriation for investigations on deciduous fruits of $50,000, and $20,000 for the citrus station at Riverside.

The total amount received by the Colorado station, exclusive of the Federal funds, was $91,440, $61,892 of this being from the State mill levy. The Connecticut State station receives only half of the Federal funds, with State maintenance amounting to $35,000 annu-

lly, the balance of the Federal funds going to the Storrs station, which receives also $12,625 from the State.

The State funds for the Delaware station amounted to $10,000 nnually. The Florida station received $5,000 and the Georgia tation $8,000.

The total State appropriation for the Idaho station was $27,150, nd the Illinois station received State support amounting to $195,500. The receipts of the Indiana station, other than Federal, were $75,000 ppropriated for maintenance of the station, with $117,966 from the eeding-stuffs and fertilizer control, a special swine-disease fund of 15,000, the creamery-license and stallion-enrollment fund of $24,772, he experiment-orchard fund of $1,600, and the Moses Fell Annex und of $22,297.

The Iowa station received $134,750 for support and $88,961 for oil survey. The State appropriation for the Kansas station was 93,800. The funds used specifically for experiment and research at he Kentucky station were $50,000 direct State appropriations, the se of the feeding-stuffs and fertilizer fees up to $44,000, and $20,000 f the sales fund.

The income of the Louisiana station included $26,541 of State funds nd $18,115 from sales. The State appropriations for the Maine tation are $5,000 for the Highmoor farm, $5,000 for the Aroostook arm, and $5,000 for animal husbandry investigations. The Maryland station receives $27,576 from the State, with an additional sum f $6,608 for the Ridgely farm and $22,030 from sales. The Massachusetts State appropriation for the station for the year was $55,875, with an additional sum of $18,632 from fees, sales, and miscellaneous ources.

The total income of the Michigan station, exclusive of Federal unds, was $139,700, which included $779 for the South Haven tation, $8,624 for the Upper Peninsular station, receipts from the ertilizer and feeding-stuffs control, and miscellaneous. The total tate receipts of the Minnesota station were $371,272, of which 257,173 was direct appropriation and $82,843 from sales. Of this, 242,238 was used at the central station, the balance going to five ubstations. The last Legislature of Mississippi made appropriations otaling $46,300 for the biennium, for the central station, for specific urposes, including farm management, horticulture, poultry, dairy, lant diseases, purchase of live stock, and for printing bulletins. The Iissouri station received $18,035 from the State, $16,204 from sales, 38,972 from the fertilizer control, with additional special appropriations of $10,900 for farm crops and $8,988 for soil survey. The Iontana Legislature appropriated $110,500 for the station and ranch stations, which also had a sales fund of $27,342.

The Nebraska station received approximately $90,540 from the State and sales. The North Platte substation expended about $60,000, the Scotts Bluff substation $8,000, and the Valentine substation $10,000. The Nevada station receives no State funds, and the sales amounted to only $320. The New Hampshire station also received no State support, but had sales and miscellaneous funds amounting to about $17,000.

The total State appropriation for the New Jersey station was about $227,000, most of it for specific purposes and departments, not all of a research nature, as the egg-laying contest, mosquito control, etc. State appropriations for the New Mexico station were $7,500, supplemented by a sales fund of $6,323. The New York Cornell station receives from the State $109,022; from fees, $12,420; from sales, $14,837; and from miscellaneous sources, $2,897. The New York State station receives an appropriation of $146,196. The North Carolina station had the use of $112,150 of funds from the State department of agriculture for experimental work.

The total income of the central and branch stations in North Dakota, exclusive of Federal funds, was about $150,000, besides $6,000 from the Flax Development Committee for flax investigations and $850 from the Durum Milling Association. The total sales funds were $58,187.

The Ohio station received $279,035 from the State, specifically appropriated, supplemented with a sales fund of $56,675. The State appropriations for the Oklahoma station were $10,000, being a $5,000 increase over previous years, with an additional fund from sales of $5,000. The income of the Oregon station from the State is $86,500 supplemented by $2,000 from local communities and a sales fund of $18,533. The State fund is rather specifically appropriated.

The Pennsylvania station received a biennial State appropriation of $6,000 for tobacco investigations. A part of the general State appropriation to the school of agriculture, supplemented by the receipts from sales, is used for research.

The Rhode Island station receives no State aid, with the exception of $2,000 that was to be used for increasing salaries of the station staff. The South Carolina station also receives no State support but an appropriation of $25,000 was made for the substations, for starting a beef-cattle investigation, and for cooperative fertilizer experiments. About $9,500 is received from Clemson College and the sales funds amount to about $3,000. The only State aid for the South Dakota station is a printing fund of $1,500, with a sales fund of about $4,500. The State appropriates $13,500 for the branch stations. The total State income for the Tennessee station, including the branch stations, is about $52,000, with a sales fund of about $16,000. The Texas station receives a total of $213,540 from the

State, including $6,000 for experimental apiaries. The sales fund at the central station is about $14,960 and at the branch stations $62,650.

In Utah the State appropriated $100,000 for the biennium for the station. Davis County contributes $1,000 per year and furnishes the land for an experimental farm in the county, and Uintah County contributes $2,500 for a soil survey of that county. The sales fund at this station was about $19,500. The Vermont Station receives no State appropriation.

The direct State appropriation for the Virginia station was $39,450, with sales and miscellaneous receipts amounting to about $22,000. The Washington station, exclusive of the branch stations, received $50,000 from the State, and $43,043 from sales. The receipts at the West Virginia station were $45,000 from the State for maintenance, $15,000 for buildings and improvements at the central station, $7,500 for buildings at the Reymann memorial farms, and a sales fund of $21,940.

The expenditures from State funds at the Wisconsin station were $162,527. The Wyoming station receives $10,000 for experimental purposes, with $20,000 for the branch stations and a sales fund of about $4,400.

Twelve stations receive over $100,000, exclusive of Federal funds, as follows: Ohio $279,035, Minnesota $257,173, Iowa $222,750, Texas $213,540, Illinois $195,500, California $149,085, New York State station $146,195, North Carolina $112,150, Montana $110,517, New York Cornell station $109,022, Michigan $104,870, and Nebraska $101,703. Five stations receive some State aid, but less than $10,000, and six stations receive no direct State support.

CHANGES IN PERSONNEL.

Changes in personnel continued to be large, due to the same causes as were mentioned last year, namely, low salaries and more opportunities in commercial lines. Where this involves heads of departments, as it has in many instances, it invariably causes more or less disruption in the investigational work of the station, resulting often in the abandonment of projects that are in progress.

A certain amount of change, involving the advancement of assistants to better and more responsible positions after sufficient experience has been secured is of course legitimate and to be encouraged, but every effort should be made to retain those members of the staff in charge of the project work. During the year there was a change in the directorship of seven stations, including those of Arkansas, California, Delaware, Indiana, Louisiana, Massachusetts, and Oregon. This is a comparatively large number. Over fifty heads of departments resigned, with increasing numbers through the grades of asso-

ciates and assistants, the total changes in some stations amounting to over fifty.

Another serious aspect of this situation was the difficulty in securing men to fill the positions vacated, especially with candidates who are familiar with the local conditions in the State where they occur, which is often advantageous. This emphasizes the apparent lack of men who are training themselves for research work.

A mitigation at least of this constant large change in personnel will come when the stations can offer more adequate salaries, which is gradually being accomplished, and further improvement may be looked for when the station, as the research branch of the institution with which it is connected, takes its merited place as the highest of the institutional activities.

When a high type of research man goes into a commercial position, much of the value of his work is lost to the direct and free use of the public. If he is worth the increased salary to the commercial house, he is certainly worth it to the community, and should receive remuneration sufficient to make his position acceptable. Many cases have occurred where high-grade research men have resigned from station work, not because they were in any way dissatisfied with the opportunities offered them, but because they could not afford, from a monetary standpoint, to remain in their positions. Some of the more important changes are noted as follows:

At the Alabama station, Dr. G. L. Peltier, head of the plant pathology department, resigned to accept a similar position at the Nebraska station. At the Arizona station a plant pathology department was added and J. G. Brown, formerly assistant in biology, was placed in charge.

Director Martin Nelson, of the Arkansas station, was succeeded by Dr. Bradford Knapp. Director H. J. Webber, of the California station, resigned at the end of the fiscal year and was succeeded by Dr. C. M. Haring.

At the Colorado station, Dr. W. W. Robbins, head of the botany department, resigned to take a position with a beet-sugar company, and was succeeded by Dr. A. K. Peitersen, of the Vermont station. The plant pathologist, J. H. Leach, resigned, and was succeeded by C. D. Learn, of the Oklahoma station. F. J. Chase was appointed to have charge of the farm-management work. Dr. W. G. Sackett, bacteriologist, returned after a year's leave of absence.

Director Harry Hayward, of the Delaware station, was succeeded by C. A. McCue. The agronomist, A. E. Grantham, resigned and G. E. Schuster was appointed to the position. L. R. Detjen, from the North Carolina station, was appointed associate horticulturist.

The plant physiologist of the Florida station, B. F. Floyd, and the chemist, S. E. Collison, left to go into commercial lines, and were

succeeded by Dr. R. W. Ruprecht. T. E. Keitt, chemist of the Georgia station, resigned. T. S. Buie was appointed agronomist.

At the Idaho station, Dr. P. P. Peterson, soil technologist, resigned, and G. R. McDole, from the Minnesota station, succeeded him as associate agronomist. Dr. J. J. Putnam, of the bacteriology department, severed his connection with the station, and Dr. Paul Emerson, head of that department, resigned and was succeeded by Dr. W. M. Gibbs. H. P. Davis was appointed head of the dairy department and vice director of the station. S. P. Smyth was placed in charge of the poultry department, to succeed Pren Moore, resigned. Other resignations included the professor and associate professor of agricultural engineering, the associate animal husbandman, and the veterinarian.

At the Illinois station the staff was reduced 25 per cent below its normal number, the severest loss being the death of Dr. C. G. Hopkins, vice director and agronomist, who died on his way home from Greece, where he had been to assist in stimulating agricultural production during the war. Dr. W. L. Burlison was appointed to succeed him as agronomist.

C. G. Woodbury, director of the Indiana station, resigned, and was succeeded by G. I. Christie, previously director of extension, who combined the duties of the two offices. A number of other changes occurred that did not involve heads of departments.

The changes at the Iowa station were quite numerous, involving [illegible]1 appointments and 16 resignations, mainly among the assistants. At the Kansas station the head of the department of agricultural economics resigned and a number of assistants were appointed.

Changes at the Kentucky station included the appointment of Dr. W. D. Valleau, of the Minnesota station, as plant pathologist, [illegible]. L. Jackson as vegetable histologist, and R. H. Ridgell, of the Arkansas station, as fertilizer chemist, succeeding W. Rodes.

Director W. R. Dodson, of the Louisiana station, resigned at the end of the fiscal year, and was succeeded by Dr. W. H. Dalrymple. Dr. F. W. Zerban, sugar chemist, and Dr. N. Kopeloff, bacteriologist, resigned to go into commercial lines. A. F. Kidder, agronomist in the college, was appointed agronomist to the station, and assistant director A. P. Kerr was appointed chief chemist.

At the Maine station, Dr. F. M. Surface resigned as biologist and was succeeded by Karl Sax.

F. W. Morse continued as acting director of the Massachusetts station until the end of the fiscal year, when S. B. Haskell was appointed director. Dr. J. K. Shaw, pomologist, resigned to accept a position at the West Virginia university and station, but returned before the close of the year. W. W. Chenoweth was appointed head of the department of horticultural manufactures. F. A. Waugh, of

the horticultural department, Dr. G. E. Gage, animal pathologist, and J. C. Graham, poultryman, were reinstated from leave of absence for war service.

At the Minnesota station, Dr. L. S. Palmer, of the Missouri station, was appointed dairy chemist, and Dr. J. D. Black, chief of the division of agricultural economics, the latter succeeding Dr. W. W. Cumberland. C. P. Bull resigned as associate agronomist. Dr. C. W. Gay, chairman of the animal husbandry group, and H. W. Vaughan, head of the swine section, resigned. W. H. Alderman, from West Virginia, was appointed head of the horticultural department. There were 16 appointments and 12 resignations among the assistants.

At the Missouri station, Dr. E. F. Hopkins was appointed plant pathologist. A. C. Dahlberg resigned as associate in dairy husbandry, also R. R. Hudelson, associate in soils, and T. J. Talbert, associate in horticulture.

Changes at the Montana station included the resignation of A. Atkinson, agronomist, to become president of the State college, and the appointment of P. V. Cardon to succeed him. O. B. Whipple, of the horticultural department, resigned.

L. W. Chase, head of the agricultural engineering department of the Nebraska station, resigned and was succeeded by O. W. Sjogren. Dr. E. M. Wilcox, of the plant pathology department, was succeeded by Dr. G. L. Peltier from Alabama.

J. H. Gourley resigned from the horticultural department of the New Hampshire station to accept the position in the West Virginia university and station vacated by Dr. J. K. Shaw and was succeeded by G. F. Potter. Dr. H. R. Kraybill was appointed station chemist.

David Lumsden, of the department of floriculture at the New York Cornell station, resigned during the year.

Dr. J. O. Halverson was appointed to take charge of the animal nutrition investigations at the North Carolina station.

At the North Dakota station the chemist, J. W. Ince, resigned and was succeeded by L. T. Anderegg, who also resigned and was succeeded by T. H. Hopper. Other resignations included Dr. C. Yampolosky, plant pathologist, G. B. Rogers, dairy husbandman, and T. A. Hoverstad, in charge of market investigations, the latter being succeeded by W. R. Porter.

Dr. A. B. Cordley resigned the directorship of the Oregon station remaining as dean of agriculture, and was succeeded by J. T. Jardine. W. S. Brown was appointed head of the horticultural department succeeding Dr. C. I. Lewis. G. V. Copson was appointed head of the department of bacteriology.

At the Pennsylvania station, W. C. Pelton was appointed in vegetable gardening. Three associate professors resigned—E. L. Worthen

the agronomy department; G. S. Bulkley, of the dairy department; nd W. H. Darst, of farm crops. The appointments included 36 ssistants and instructors, and there were 15 resignations.

Dr. P. B. Hadley, in charge of the animal breeding and pathology ork at the Rhode Island station, was succeeded by Dr. H. G. May. . V. Starkey was appointed head of the animal husbandry department of the South Carolina station, succeeding R. L. Shields. Dr. C. . Ludwig succeeded G. W. Wilson as associate in botany and plant athology at that station, and W. J. Young was appointed associate orticulturist, to succeed L. H. Leonian, and later resigned. Dr. A. . Evans was appointed associate agronomist at the South Dakota ation.

At the Tennessee station, Dr. G. A. Metcalf, veterinarian, resigned the end of the year, and the consulting meteorologist, J. F. Voorhes, resigned to leave the State. Three of the station staff—C. A. illson, of the animal husbandry department; Maurice Mulvania, acteriologist; and O. M. Watson, horticulturist—were transferred to e university, station work in these lines being discontinued. C. E. llred was appointed head of the agricultural economics department.

At the Texas station, H. H. Laude, agronomist, resigned, and r. A. B. Cox succeeded H. M. Eliot as chief of the division of farm d ranch economics. F. B. Paddock, of the entomology department, resigned and was succeeded by Dr. M. C. Tanquary.

W. W. Henderson, of the entomology department of the Utah ation, resigned to accept the presidency of the Brigham Young ollege, and Dr. B. L. Richards returned from work at the University Wisconsin as associate plant pathologist.

At the West Virginia station, E. A. Livesay was appointed head the animal husbandry department. Dr. J. K. Shaw, from Maschusetts, was appointed horticulturist (and later resigned), succeedg W. H. Alderman, who went to the Minnesota station. F. W. emple, the agronomist, resigned.

While many changes occurred in the Wisconsin station, they did t involve any heads of departments. At the Wyoming station, e associate chemist, K. T. Steik, resigned. Dr. J. W. Scott, rasitologist, was on leave of absence for the year, and Dr. J. I. ardy resigned as wool specialist.

STATION PUBLICATIONS.

The increasing cost of paper and printing, coupled with straitened ancial circumstances, has made it impossible for many of the stans to keep up in the publication of their work. Many manuscripts held back because of inability to print them, and accounts of periments which have been in progress for a considerable term of ars are not prepared for publication for the same reason. The pub-

lishing item has become a heavy one with many stations. In notable instances it amounts to approximately $20,000, while in even the smaller institutions it amounts to $5,000 or more.

During the year the experiment stations issued 927 separate publications, embracing 22,275 pages. This represents a quite steady decrease for several years past. For instance, the number of publications was about one-third less than in 1914, and the total number of pages was little more than 10 years previous.

Furthermore, lack of funds has tended to decrease the size of the editions and has necessitated revision of the mailing lists, with special attention to limiting the number sent outside the States. In 1920 the mailing lists aggregated 933,933 names, while for many years it was considerably over a million. In a few cases, as an economy measure, announcements have been made of forthcoming publications and the distribution in large measure restricted to those who applied for them. There is still, however, a very wide circulation of bulletins outside the States in which they are issued, indicating in a striking way the fact that the work of these institutions is not merely of local interest and use.

To increasing extent the stations have published technical accounts of their work in various scientific journals of the country. Their manuscripts have been readily accepted, and publication in these journals serves to bring them to the attention of specialists most interested in them. A point has been reached, however, where such publication is less feasible than formerly, as most of these private journals are adjusting themselves to higher costs, and consequently have large accumulations of manuscripts, which delay issue. Several of the stations continue to publish technical series of bulletins devoted to investigations which have not reached a stage at which they are of general interest.

In a number of States larger attention is being given to keeping the public informed regarding the work and services the stations are doing. Many of the colleges now have editorial or publicity departments which the stations are able to take advantage of. Such publicity is very desirable and might well be made a more general feature.

NEW BUILDINGS AND EQUIPMENT.

Comparatively few larger buildings were added to the equipment of the stations during the year, due mainly to the high cost of materials and the limitations on the income of the stations. Equipment, apparatus, and live stock was, as a rule, maintained without any very large additions. The following items on equipment are noted:

The Arizona station added a foreman's house and machinery shed at the Salt River Valley farm and a barn at the Prescott dry farm

Additional land was acquired at Yuma for an extension of the date orchard. An appropriation of $4,000 for a new dairy barn and $500 for a hog house, at the station at Tucson, became available.

The Arkansas university and station secured a farm of 423 acres, located $1\frac{3}{4}$ miles north of the campus, of which 60 acres are to be devoted to horticulture, 120 to agronomy, 10 to plant pathology and entomology, and the balance to pasture and general farming.

At the Colorado college and station a new physics building costing $93,000, a veterinary building costing $35,000, and a horse barn costing $3,500, were nearly completed. While the buildings are mainly for college use, they will be of considerable help to the station in extending its facilities.

Three small silos were built at the Connecticut Storrs station, fences costing about $650 were constructed, and a flock of 33 sheep was added to the live stock.

At the Idaho station a poultry building, costing about $1,500, was added and two students' Army Training Corps buildings were transformed into a storage building for horticultural and farm crops at a cost of $600. A feeding barn and silo, costing $4,500, were erected at the Caldwell substation, and a sheep barn and machinery shed at Sandpoint, at an expense of $600.

The Indiana station secured a 5-years' lease of a farm, which will be devoted to swine experiments. A model country house, new barn, and tool shed were erected on the Wilson farm, and a barn and poultry house are being built on the Bedford farm. At the university a horse barn, costing $30,000, and a cattle barn, costing somewhat more, with concrete silos, were completed.

The Iowa station has $75,000 available for the purchase of a farm, near the college campus, which will be used by the animal husbandry department. Numerous minor improvements were carried out at the Kentucky station, including repainting of all of the barns, fencing, road building, and the installation of new equipment in the dairy barn. An abattoir with a refrigerating plant was completed and considerable live stock added. The Louisiana station also reports considerable repair work and additional apparatus in many of the departments.

The Maine station lost by fire all of the records of a series of years' work on genetics. At the Aroostook farm the roof of the barn fell in, from snow load, costing about $1,700 to replace, and the tool shed at Highmoor was burned, with a loss of $1,838. A new cattle barn is being erected at the Highmoor farm.

The Michigan station secured a farm of 40 acres at Chatham for $4,000, and a small laboratory was constructed for work with small animals. Additional facilities for both the station and college have

been provided in horticulture, forestry, and plant physiology and pathology, by the remodeling of the horticultural and agricultural botany building, at a cost of $90,000. The Missouri station has rented a farm of 330 acres for animal husbandry work.

At the Nebraska station the animal pathology laboratory was finished at a cost of $60,000, thus completing the entire plant, which has cost about $125,000. Tractor-testing equipment was installed, valued at $35,000. On the agronomy farm a hay shed costing $2,500 and a machine shed costing $1,000 were erected. At the Union fruit farm, a residence costing $4,500 and a barn costing $1,800 were completed. New buildings at the North Platte substation included a horse barn costing $20,000, a residence costing $4,200, and buildings and equipment for the poultry plant costing $7,000.

A new horticultural building was under construction at the New Jersey station, and additions were made to the soil house. The New Mexico station built a four-room adobe residence for the poultry department.

The agricultural college at Cornell University is to add four new buildings, from an appropriation that will eventually amount to about $6,000,000. Part of these will be devoted to research and will directly benefit the station.

At the Ohio station, a new block of greenhouses, costing about $9,820, was completed and occupied. A new dairy barn has been provided for at the Oklahoma station, which will probably be completed during the coming year. A house was erected on the agronomy experiment station farm, for the foreman. Six experimental silos and considerable equipment and apparatus were added to the Oregon station.

At the Porto Rico station, two warehouses from the military camp at Las Casas were converted into three residences for members of the station staff.

A calf and a hog barn were erected at the South Carolina station, costing about $6,000 each, and an office building and corn barn were added to the Pee Dee substation. At the Tennessee station, two large barns were completed on the Cherokee farm. The buildings under construction at the middle Tennessee station include an administration building, stock barn, horse and implement barn, dairy barn, and four cottages for laborers.

A new water tower was constructed at the Texas feeding and breeding station, with a capacity of 30,000 gallons, at a cost of $5,000.

During the year, the buildings provided by the last Legislature of Utah were completed and occupied. The irrigation and drainage department is now housed in the new agricultural engineering building, and the plant pathology and agronomy departments in

the plant industry building. A seed house for the agronomy department and a new horse barn have been completed and occupied.

At the Virginia station, a laborer's cottage costing $2,300 was built. The station has purchased a tract of 36 acres at Bowling Green and erected a cottage and barn at the substation there at a total cost of $5,700. Experiments in sun-cured tobacco will be carried on.

Work was begun on a new dairy building at the Washington station, to cost $100,000. The legislature appropriated $35,000 for an experiment station for irrigation farming at Prosser, on a tract of 205 acres, and the erection of buildings was begun.

At the West Virginia station, barns were completed on the agronomy farms and needed equipment added to all departments.

A student army barracks at the Wisconsin station was remodeled for an experimental hog-feeding barn. At the Wyoming station two rooms were added to the foreman's house on the agronomy farm, and the horse corral was rebuilt. At the stock farm a double house was built for the men, and a steer-feeding shed and hollow-tile silo erected.

NEW LEGISLATION.

In most States the legislature did not meet during the year or no legislation affecting the station was enacted. Those States where such action was taken are as follows:

In Alabama, the first State appropriation for the central station for work at Auburn was made, to take effect October 1, 1919, carrying $5,000 for the first year and $7,500 each for the next three years. An appropriation was also secured for animal husbandry work of $10,000 a year for two years and $12,500 a year for the two following years, which, while entirely independent of the station, may be used for college equipment, and may thus aid in experimental work.

The Arizona Legislature appropriated $10,000 for the purchase of land on the Yuma mesa to increase the experimental work being done in citrus investigation, and chapter 153, Session Laws, 1919, placed upon the irrigation department the task of carrying out extensive water-supply investigations in Cochise County. At the California station three new lines of work were provided for by special appropriation, including $5,000 for deciduous-fruit investigations, for which a branch station has been established at Mountain View; $4,000 for range experiments in beef production, to be carried out on 4,000 acres of leased land at Shingles, Eldorado County, with the use of 27,000 acres of forest reserve; and alkali investigations at Fresno. The Georgia Legislature appropriated $25,000 for a coastal plains station at Tifton, the local community giving also $25,000 and land. A law was also passed requiring all printing of State institutions, including

the station, to be done on requisition filed with the State superintendent of printing, this applying to letterheads and forms as well as bulletins.

The Louisiana Legislature authorized the State Board of Agriculture and Immigration "to establish at some suitable and accessible point in the strawberry and truck-growing belt of the Louisiana Parishes a branch of the State experiment station, for the purpose of carrying on scientific and practical investigations pertaining to the most economical production of the strawberry, other fruit and truck crops in general, preservation of soil fertility, irrigation, and drainage, the ravages of insect pests and fungus diseases and means of combating them, the study of the varieties of strawberries, fruits, and truck crops, the grading, marketing, and other problems that are or may become vital to the development and maintenance of the fruit and truck industry of Louisiana."

In Maryland, while there was no direct State law affecting experiment station work, the General State Budget Law, Central Purchasing Agent Law, and Merritt System Law, all affect the station, making the available funds less flexible and imposing many regulations which retard progress, entailing much detailed clerical work, which adds to the expense of transacting the station business. The Massachusetts station also suffers from the supervision of all of its financial affairs by the State superintendent of administration, the system imposing many hardships on the station in the free use of its funds, both Federal and others. Estimates and appointments must be made dating from December 1 to June 1, and then to December 1, and it is practically impossible to secure changes in any salary or the appointment of new men between these dates, even to meet emergencies. The purchase of material and authority for travel, especially outside of the State, involve much delay. The regulations are proving a considerable handicap and are clearly unsuited to the needs of a research institution in which circumstances may require the taking up of lines which may arise from an emergency or materials which can not be prophesied in advance. The requirements and their effects are such as to raise a question whether the State is not exceeding its authority in thus restricting the use of the Federal funds.

The Minnesota Legislature no longer makes an appropriation direct to the station or for special agricultural investigation, but the financial needs of the station are included in the general budget of the university as a part of that of the college of agriculture.

In Mississippi the last session of the legislature authorized the establishment of a new branch station, locating the same at Raymond, in Hinds County. The appropriations include $6,000 for the purchase of land, $6,000 for buildings, and $5,000 for each of the years 1920 and 1921 for support.

As a result of an initiative vote, the University of Montana will receive from a bond issue $3,750,000 for building purposes, of which $1,500,000 will accrue to the college of agriculture. In addition, an amendment to the State constitution was voted whereby the various institutions grouped under the University of Montana will receive a 1.8-mill maintenance tax.

The 1920 session of the New Jersey Legislature amended the Glassware and Testers' License Law, giving additional powers and finances to the station, making it possible to adequately enforce the law. An enabling act, known as Chapter 126, was passed, giving the power to carry out investigations on the biology of sewage disposal. An act was also passed authorizing the experiment station to superintend poultry shows, to stage educational exhibits, and to offer premiums at said shows, carrying with it an appropriation of $10,000, $4,000 of which was made available for the current year's work. The old Vineland Contest Act was repealed and a substitute act passed authorizing the supervision of three such egg-laying contests and breed-testing stations and an appropriation of $13,000 for the work, of which $10,000 was made available for the current year.

The Oklahoma station received $10,000 for maintenance, as a direct appropriation from the legislature for the first time, it being previously set apart by the college for the station. In May, 1920, the people of Oregon approved a millage tax measure providing additional funds for the resident instruction work of the college. While no part of the funds from this tax or from the original millage tax of 1913 is devoted to station work, more adequate provision for resident instruction is of incidental advantage to the station work. The withdrawal of the Federal appropriations for irrigation agricultural investigations at the Umatilla station, for cereal investigations at the Burns station, and for forage-crop investigations at the Moro station made it difficult to conduct the work at these stations effectively.

The Legislature of South Carolina appropriated $25,000 a year each for the central and branch stations, to relieve the college and supplement station funds. This is an important innovation, as heretofore the station has received no funds directly from the State, but its local support has come from the college tag-tax fund.

The Virginia Truck Experiment Station was made a permanent State institution by the General Assembly, to be under the control of a board of directors consisting of five members, two of whom shall be the chairman of the board of control of the Virginia Agricultural Experiment Station at Blacksburg and the president of the Virginia Polytechnic Institute. The law also provides that the same board of directors shall have the management and control of the

Eastern Shore Experiment Station, located near Onley, Accomac County.

In Wyoming nine farms formerly in charge of a State farm board were placed in charge of the station, with appropriations amounting to $25,000 for their support.

SUBSTATIONS.

The establishment of substations or branch stations supported by State or local funds has been adopted in many States. A number of the stations carry on extensive cooperative field experiments with representative farmers or on leased lands over the State, endeavoring as a rule to cover the more important soil types. In many States both systems have been adopted.

The plan of extending the experimental work to typical sections of the State has been found advantageous, and in some cases quite essential to a study of local problems. In addition to the broad testing of results secured at the central station, such work brings out the local adaptation which may be necessary.

The establishment of branch stations on land owned by, and therefore under permanent control of, the station is the more satisfactory arrangement of the two systems, as the investigations are assured of unbroken continuance, the laying out and oversight of the work can be carried on to much better advantage, and any improvements, buildings, drainage, fencing, etc., remain as permanent additions.

In default of this a good system of experiment fields over the State affords much needed opportunity for more extensive trials under differing conditions than would be possible at the central station. In practically all States there is a wide divergence of conditions as to soil, altitude, rainfall, and climate, and oftentimes in the particular lines of agriculture practiced, and without provisions of some kind for work over the State it is difficult for a station to reduce its results to a point where they may be safely turned over to the extension service.

In many States the branch stations have received liberal support and have been developed on quite an extensive scale, with permanent plats and plantations, and provision for feeding trials on an extensive scale. As a rule they are not provided with laboratory facilities, being devoted to agronomical, horticultural, or live-stock experiments in the field. They therefore have their limitations, but where they are under the immediate supervision of the director and staff of the central station the work can be maintained on a satisfactory grade and coordinated with that of the main station.

The following is a list of such outside activities of the stations, omitting the more general cooperative work with farmers which is

carried on to a greater or less extent by nearly all the stations. Many of these outside activities are conducted in cooperation with the U. S. Department of Agriculture.

In Alabama cooperative experiments are conducted under the State local experiment funds, with over 200 cooperators in the State. The station has no branch stations.

The Arizona station conducts two dry-farm substations, located at Cochise in the Sulphur Springs Valley and at Prescott; two experiment farms, one at Mesa in the Salt River Valley, and the other at Yuma; and a date-palm orchard at Tempe, with a small orchard at the Yuma substation.

The California branch stations include the farm located at Davis, devoted to general agriculture and horticulture, the citrus experiment station at Riverside, the station in the Imperial Valley near El Centro, where field and horticultural problems are studied, the Kearney farm at Fresno, for field and horticultural experiments, the deciduous-fruit station at Mountain View, and two forestry stations at Santa Monica and Chico. In addition, range experiments are carried on at Shingles and Placerville, and alkali and other problems are studied at Fresno.

The outside activities of the Colorado station include the Plains station at Cheyenne Wells, devoted to dry-land work with field crops, fruit, and dairying; the high-altitude station at Fort Lewis, at an altitude of 7,000 to 9,000 feet, devoted to crop adaptation; the Arkansas Valley station at Rocky Ford, for experiments with alfalfa and corn especially; and the Akron dry-land station, where experiments are being made with summer fallow and sheep pasturage.

In Florida a branch station has been established at Lake Alfred for the citrus industry; a substation has been provided for at Quincy for tobacco experiments, and land and funds set aside for a station in the Everglades.

The Georgia station conducts no branch stations, but the State supports an independent institution, under an entirely distinct governing board, at Tifton, under the name of the Coastal Plains Station.

The substations in Idaho include Caldwell, devoted to diversified farming and live stock; Aberdeen, used for irrigation experiments; the high altitude station at Felt; the cut-over-lands station at Sandpoint for work with cattle, hogs, and land clearing; and a horticultural substation at Jerome.

The agronomy department of the Illinois station conducts 27 cooperative experimental fields over the State for work on soil fertility, and the horticultural department maintains field and orchard experiments at Olney and Anna.

The Indiana station conducts a farm at Bedford (the Moses Fell Annex) for crops, fertilizers, spraying, alfalfa, and soil management; the Pinney-Purdue farm at Wanatah, for soil-fertility studies on unproductive sandy soil; and a forestry station at Farmland.

The outside activities of the Iowa station include a fruit-breeding farm at Charles City, an orchard at Council Bluffs, and some 80 cooperative experimental fields on important soil types.

The Kansas station operates substations at Garden City for irrigation and dry-land agriculture, at Fort Hays for work with crops and live stock under semiarid conditions, at Colby for irrigation studies, and at Tribune for dry farming.

The Kentucky station has no branch stations, but operates a number of experimental fields over the State, some owned by the station and some conducted cooperatively.

The branch stations in Louisiana include the Sugar station at Audubon Park, New Orleans; the station at Calhoun, devoted to both field and live-stock work; and the rice experiment station at Crowley. The station also cooperates with the U. S. Department of Agriculture at the New Iberia live-stock experiment farm, and will probably establish a fruit and truck station in Tangipahoa Parish.

The Maine station has two branch stations, the Aroostook farm at Presque Isle for potato studies and the Highmoor Farm at Monmouth for fruits, field-crop, and pasture studies.

The Maryland station has one branch station, at Ridgeley.

Two branch stations are conducted in Massachusetts, the market-garden field station at Lexington and the cranberry substation at Wareham.

The Michigan station conducts the Upper Peninsular substation at Chatham, devoted to land clearing, crop production, live-stock breeding, grading, and feeding; the South Haven station, devoted to horticulture; and the Graham farm, near Grand Rapids, for investigations in horticulture, cover crops, and breeding small fruits.

The substations in Minnesota include the north central experiment farm at Grand Rapids, the northeast demonstration farm at Duluth, the northwest experiment farm at Crookston, the west central experiment farm at Morris, the southeast demonstration farm at Waseca, the fruit experiment farm at Zumbra Heights, and the Cloquet forest experiment station.

The Mississippi station conducts branch stations at Poplarville for field and truck crops and horticulture; at Holly Springs for field, horticulture, and dairy studies; the delta station at Stonerville; the Raymond branch station; and continues some cooperative work at the McNeill station, although this has been largely transferred to the Bureau of Animal Industry of the U. S. Department of Agriculture.

The Missouri station has no branch stations under its control, but conducts a number of soil experiment fields over the State. Separate stations for fruit growing and poultry raising are maintained by the State at Mountain Grove.

The Montana station conducts five substations, including the horticultural substation located at Victor near Corvallis, in the Bitter Root Valley; the North Montana station at Fort Assinniboine, near Havre; and the Judith Basin dry-farm station at Moccasin. It also conducts the Fort Ellis farm near Bozeman, devoted to dry-land farming and live-stock experiments, and cooperates with the U. S. Department of Agriculture in experiments at the Huntley substation on a reclamation project near Billings.

There are substations in Nebraska, at Scotts Bluff, for soil fertility, forage crops, and irrigation farming; at Valentine, for forage crops and dairying; and at North Platte, for work in animal husbandry, agronomy, and dairying. A fruit farm is conducted at Union, about 40 miles from the central station (Lincoln).

Nevada and New Hampshire have no substations. The New Jersey station has no branch stations, but conducts the Vineland international egg-laying and breeding station, and also cranberry work at Whitesbog in Burlington County.

The New Mexico station cooperates with the U. S. Department of Agriculture in experiments on the dry land field station at Tucumcari, devoted to rotations, tillage methods, hog pasture, and variety tests.

In North Carolina the substations include the coastal plains station, on the Pender farm at Willard, the Piedmont station at Statesville, the Blackland farm at Wenona, the Black Mountain farm, a tobacco station at Oxford, and a test farm at Rocky Mount.

In North Dakota substations are maintained at Langdon, devoted to fruit, cereals, and crop rotations; at Hettinger for dry-land farming and live stock; at Edgeley for fruit, rotations, pastures, and pork production; at Dickinson for dry-land farming, and at Williston for live stock.

The branch stations in Ohio include the northeast test farm at Strongsville; the northwest test farm at Findlay; the southeast test farm at Carpenter; the southwest test farm at Germantown, and the Washington County truck farm at Marietta. In addition to these the station conducts a number of county experiment farms, some owned and some on leased land.

The outside activities of the Oregon station include the eastern Oregon branch substation at Union, the dry-land substation at Moro, the John Jacob Astor station at Astoria, the Umatilla substation, the southern Oregon substation at Talent, and the Harney Valley substation at Burns. In addition to these, there is an irrigation

demonstration farm at Redmond, a dry-farm demonstration farm at Metolius, and a substation at Hood River for fruit studies.

Two substations are operated by the South Carolina station, one at Florence, called the Pee Dee station, and one at Summerville, known as the coast station. In addition, a system of cooperative experiments in various sections of the State has been inaugurated.

The South Dakota station conducts substations at Eureka, Highmore, and Cottonwood, and a demonstration farm at Vivian.

Tennessee has two substations, the west Tennessee station, located at Jackson, and the middle Tennessee station at Columbia. In addition, the station conducts a tobacco experiment station at Clarksville, and carries cooperative experiments in four other localities in the State.

The Texas station owns and operates 13 substations, as follows: Beeville, devoted to irrigation, orchard, truck, and field crops; Troup, for diversified truck, fruit, and field crops; Angleton, for testing varieties of general field crops; Beaumont, working especially with rice; Temple, for investigations in cotton and cotton diseases as well as other field crops; Denton, mainly for small grains, legumes, and other field crops; Spur, for sheep and lamb feeding, and breeding experiments with field crop work; Lubbock, devoted to dry farming, windmill irrigation, and field crops; Pecos, which includes both field crop and orchard experiments; the feeding and breeding station near College Station, for live-stock feeding and breeding work; the tobacco experiment station at Nacogdoches; Chillicothe, for forage crops, small grains, and cotton; and the Sonora station, for breeding and improvement work with sheep and goats.

The Utah station maintains nine experimental farms, which include the Davis County farm at Farmington, especially for canning crops; the Panguitch farm for live stock; the Greenville farm for irrigation; the dry farm at Cedar City; the southern Utah experiment station near St. George, for horticulture; the Kanab and Widtsoe experimental farms; the central Utah station at Lehi; and the dry-farming station at Nephi.

The Virginia station supervises county experiment stations at Appomattox, Bowling Green, Holland, Chatham, and Lightfoot, and also three substations for the State Board of Agriculture, located at Staunton, Martinsville, and Charlotte Court House.

The Washington station conducts three branch stations, one at Lind, in Adams County, for dry farming; the Waterville branch, for forage problems; and an irrigation station at Prosser. The Puyallup station in the western part of the State is not under the control of the director of the central station.

In West Virginia the station owns the Reymann Memorial farm at Wardenville, and is conducting cooperative experiments with the

U. S. Department of Agriculture on cattle at Lewisburg and on tobacco at Guyandotte.

Wisconsin has three substations, one at Spooner, devoted to potato work and dairying; one at Ashland Junction for dairy, wheat, pea, and clover experiments; and one at Marshfield for drainage studies. Two experimental fields have recently been added, one at Hancock on poor sandy soil and one at Coddington on marsh soil, both for studies as to how these soils may be profitably farmed.

In Wyoming provision has recently been made for nine substations, including those at Lander, Sheridan, and Gillette, already established, the latter in cooperation with the U. S. Department of Agriculture. Others are located in the towns of Lyman, Grover, Eden, Archer, Torrington, and Jireh.

PROJECTS OF THE EXPERIMENT STATIONS.

A classified list of projects conducted by the experiment stations was compiled for the first time in 1919, as mentioned in the preceding report. The interest which this list developed as a means of keeping abreast of the work of the stations and enabling station workers, as well as those in the department, to know where certain types of investigations are being carried on, led to a revision of the list to cover the projects in operation in 1920. This list, like its predecessor, was issued in mimeographed form. It is more complete than the preceding one, enumerating over 4,200 separate projects. These cover every conceivable topic in the range of agricultural inquiry. In the classification scheme the entries are duplicated to considerable extent in order to index them more fully, and many cross-references are given.

Grouped by subjects, the list shows 1,468 projects in agronomy, 39 in horticulture, 587 in animal husbandry, 344 in diseases of plants, 340 in entomology, 109 in dairying, 164 in veterinary medicine, and 322 miscellaneous.

The largest number of entries is under the head of field crops, comprising one-fourth of the total. Corn leads the list of crops with 47 projects. Irish potatoes has 96, wheat 80, oats 69, rotations 60, and alfalfa and cotton each 57. Horticultural projects come second, with a total of 743, under which the leading headings are: Apples, 00 entries; fruits, general, 60; vegetables and truck crops, general, 9; grapes 39, peaches 32, and orchard management 31. The next largest heading is diseases of plants, with 409 entries, the crops having the largest number being potato diseases 51, tomato diseases 0, and apple diseases 29. This is followed by economic entomology with 356 projects, the leading subjects being, bees 35 entries, apple insects and insecticides 20 each, and the codling moth and corn

insects 13 each. The next largest general subject is soils, with 259 projects, under which the leading subheads are soil fertility 52 projects, soil types 29, soil flora 28, and soil surveys 18.

The animal husbandry group is led by poultry with 191 projects, followed by swine with 147, beef cattle 78, sheep 63, and horses 13. Dairy farming includes 128 projects and dairy products 80. There are 181 entries under veterinary medicine, poultry diseases leading with 40 entries.

Other main headings in the order of number of projects are fertilizers 414, rural engineering and rural economics 128 each, feeding stuffs and animal nutrition 122, genetics 97, botany 90, chemistry 69, and foods and human nutrition 57. The smallest number of entries is under meteorology with 7 projects.

The list brings out little, if any, actual duplication of work which is not necessary to meet the needs of localities or well-rounded studies of large problems. While there is a certain similarity among projects carried by different States, familiarity with the projects shows that they have specific differences and are mainly on an individual basis. While various stations are studying the same general subjects, the nature and purpose of their inquiries or experiments vary in different instances, and unnecessary or undesirable duplication is reduced to a minimum.

The average number of projects per station is 81, with 70 under the Hatch and other funds, and 11 under the Adams fund. The range represented by this average is, however, quite a wide one.

There is already evidence that the compilation of such a list of projects is bringing about a better understanding among the stations in regard to their activities, and that their work is being more specifically outlined. It has tended to remove unnecessary duplication and has gone a long way in the direction of promoting successful cooperation.

NEW LINES OF INVESTIGATION NEEDED.

A request to the stations for suggestions as to the lines of work which should and could be carried on if sufficient funds were available has brought out some interesting and significant points. The replies received emphasize the fact that not only are the stations running with a very reduced efficiency on account of the lack of sufficient research men, for whom salaries can not be provided, but that there are numerous pressing problems that demand investigation and on which the stations are called upon for expert advice that can only be secured through investigation.

Many of the stations have more or less equipment and facilities for departments that have had to be temporarily abandoned because

of inability to pay the salaries of men to carry them on. This means an enforced lack of efficiency and inability to secure results that are urgently demanded.

The replies received from almost every station brought out not only the serious disadvantages under which it was working, but indicated a number of very pressing problems of practical application which promise large returns on the amount needed to investigate them. Extracts from a few only of the replies received are given here, which will illustrate the general conditions. A complete list of the projects submitted that require more or less immediate attention would cover many pages.

Among a long list of subjects urgently needing investigation by the Alabama station are a number that would seem to be of great importance to the South, including soil-fertility studies involving the residual soil-improving or soil-exhausting effects of the principal southern crops; the carrying capacity and best means of utilizing by harvesting by animals of many crops not heretofore thus investigated; a systematic study of southern crops suitable for the silo, with lime requirements of the principal soil types and of all the southern field, forage, and fruit crops; numerous plant diseases require further investigation, including those of pecans, cowpeas, and soy beans; a number of serious insect pests should receive attention, including the bud worm, the woolly aphis, and the Mexican bean weevil; also a study of the oils and their treatment, from soy beans, chufas, and other crops, with a view to ascertaining their fitness for various industrial purposes.

In Arizona, investigational work is needed along the lines of suitable feeds for pork production in that State, as well as proper care and management of swine under the conditions peculiar to that section; furthermore, there is need of investigations on the production of live stock under range conditions, including breeding, feeding, and management.

Some of the important Arkansas problems are the place of the tractor on Arkansas farms; sheep production, especially for the rough lands of the State; the relation of frost injury to methods of cultivation and fertilization of fruit; pasture mixtures for the cotton section; farm management and marketing studies; rice insects and diseases, and the rotation of crops for rice farms; the best type of farming for cut-over lands; and the cheapest method of putting raw land into good condition for crop production.

Many of the problems presented by the California station are of wide application throughout the West. One of the most important problems of California agriculture is the successful control of the spread of alkali. The sugar-beet industry, representing a capital of $25,000,000, is threatened with total destruction if means are not

found to control curly top and render production more secure. The proper handling of large tracts of land that can only be used for dry farming is a very important problem, and the most effective methods of treating the same and the crops best adapted for them require systematic experimentation; a thorough understanding of tillage and moisture conservation is of great importance; nematode root knot has become widespread in various parts of the State and is doing serious damage to many crops, and presents a serious and difficult problem that should receive thorough investigation; the injury caused by wireworms is a problem that vitally concerns every agricultural section of the State; range investigations need attention as well as beef-production problems.

The investigations of the Connecticut State station on proteins and vitamins are of fundamental importance, and could be greatly advanced if sufficient funds were available.

In Delaware investigations are needed along the lines of insects injurious to fruits, the storage of fruits, and development of uses for by-products of the fruit industry, and problems in milk and pork production.

The Florida station has been obliged to discontinue the plant-physiology investigations and now has only four heads of departments on its staff. Many of the problems of the State are somewhat unique. The live-stock industry is a growing one, and a great many problems are waiting to be solved.

The pecan industry of Georgia is rapidly growing and the results already secured by the station have caused growers to look for further relief; the inroads of the curculio and brown rot of peaches have virtually demoralized the industry in the State; with the cotton boll weevil sweeping the State a new order of agriculture is necessary; and more funds are urgently needed for investigation of the feeding value of velvet beans, soy beans, cottonseed meal, and especially peanuts. The growing importance of hog raising demands more extended knowledge of the utilization of these products in an economical manner with the least harmful effects on the quality of the meat.

The Idaho station reports that additional investigation should be undertaken in dairy-cattle feeding, home economics, and rural sociology.

At the Illinois station funds are lacking to carry out the studies necessary to answer the many questions that arise in regard to market credit and finance. There is an inadequate staff for the study of plant and animal diseases, and the field of normal plant and animal physiology is practically untouched. Questions arise in animal feeding which can not at present be investigated; many new problems in connection with the operation of farm machinery, which is becom-

ing a constantly increasing factor in agriculture, are being submitted for investigation.

A few of the lines of work which the Indiana station desires to take up include breeding investigations with cattle and horses; a more thorough study of the diseases of horses, cattle, and sheep; a study of septic tanks; fruit-bud development; drainage investigations; soil toxicity, giving special attention to available boron and aluminum; special problems involving plant breeding and plant physiology studies; and a through study of several of the fruit diseases.

Among the numerous problems submitted by the Kansas station is expansion of the work in agricultural economics, especially in cost of production and marketing; an extensive study of the winter hardiness of wheat in the hardy winter-wheat belt; continuation of the soil survey and establishment of experiments on different soil types of the State to supplement the work of the main station; studies regarding the best methods of utilizing sorghum grain as a feed for live stock; experiments in horse feeding under present conditions; fattening cattle on grass; extension in investigations on animal diseases; control of injurious mammals; and native pest studies.

Some of the problems confronting the Kentucky station that can not be adequately investigated on account of lack of funds are cause and control of bloody murrain in cattle; development of resistant types of tobacco, and the physiology and changes involved in curing and methods of controlling same; cost of crop and meat production; method of production of hay and pasture grasses in the mountain area; orchard investigations in different parts of Kentucky; and the relation of the various soil types of the State to the application of fertilizers.

The greater need of the biological investigations of the Maine station is for maintenance of projects that are already in progress. The poultry investigations have had to be run at their lowest ebb, and the animal husbandry studies are in a very precarious state. On account of loss of members of the staff, it is doubtful if the work in cereal breeding can be continued. More productive forage and root crops are desired by the dairy farmers of the State. The important work along entomological lines which this station has done will depend upon adequate funds for their continuance.

The Maryland station has many problems in connection with the live-stock industry, particularly forage crops for hogs, and dairy problems, which can not be undertaken for lack of men and funds. The work with crops, particularly soy beans, cowpeas, vetches, and other leguminous crops as soil improvers and for forage, should be much extended. There is need for much work with pasture grass suited to different soil types in different parts of the State, and work with market-garden and fruit crops could be profitably extended.

The particular lines of work which await necessary funds at the Massachusetts station are investigations of apple diseases in the eastern part of the State; more extensive experimental work in market gardening, in soil management and plant nutrition as related to fruit trees; canning investigations; and more extensive studies in rural sociology.

The Mississippi station reports the necessity of additional funds for studies in agriculture and home economics. A complete soil survey and determination of the fertilizer requirements for the different soil types has never been made, and it is desired to carry on cooperative fertilizer experiments in each county for the different farm and garden crops to determine the fertilizer requirements.

The Montana station emphasizes the need of extension of the work in agricultural engineering, especially in drainage and irrigation problems, and also reports that agricultural economics and marketing studies should be undertaken. Considerable expansion of all of the departments is very much desired.

The needs of the Nebraska station include investigations of systems of marketing farm products and a thorough economic study of the entire marketing system from the farmer to the consumer, looking to a more direct and less curtailed system. Fundamental research in chemistry as it relates to soil fertility, animal nutrition, and plant growth should be largely increased. It is desired to make investigations on the part played by ash, protein, and the vitamins in economic pork production, and similar studies should be undertaken in the feeding of young chicks to secure healthy and rapid growth, together with economic production; investigations of the diseases of the honeybee and of honey-producing plants to increase production in the State is very important; more extended studies of the relation of barberry to the spread of wheat rust should be made, investigation of potato diseases should be greatly extended; surveys are needed to determine the extent of acid soils in the State, as an aid to increased production; also investigations to determine the most efficient methods of handling range pastures in order to extend and protect their grazing qualities.

In Nevada, stockmen are showing great appreciation of the value of feeding experiments and studies of poisonous plants, and are demanding further information which can be gained only by a long series of experiments, facilities for which are lacking. The station has found it necessary not only to reduce its working force, but also to concentrate in a few lines the work it is able to do for the important live-stock industry of the State.

Among the needed investigations at the New Jersey station are a chemical study of the potash requirements of the soils of the State; studies on market milk production and dairy cattle nutrition; farm

management studies, including farm power in relation to farm efficiency; cost of marketing and cost of production of various crops; the improvement of farm crops by breeding and selection; further studies in all lines of plant diseases, including truck, fruit, and field crops; studies on the oriental peach moth, and dusting investigations. Investigations are also needed in connection with peach yellows "and little peach," as well as many floricultural problems.

The New Mexico station reports the necessity of further investigations on the improvement and management of New Mexico poultry; studies on the improvement and management of range cattle and sheep; investigations, surveys, and eradication of New Mexico poisonous plants and shrubs; a study of *Atriplex canescens* in respect to its range of adaptability as regards altitude, soil moisture, soil, rainfall, and temperature, as well as the development of methods of eradicating it in a practical way; also studies on the keeping qualities of different varieties of fruits and vegetables under arid climatic conditions.

Some of the projects that await the necessary funds for development at the New York Cornell station are, the rearing of calves on milk substitutes and the protein requirements for milk production; the effect of maturity on the value of corn for silage when used in milk production and a thorough study of means of increasing the value of pastures should be undertaken. The station is also desirous of making a study of the extent of variability in lime and fertilizer requirements in each soil type found in the State.

The Oklahoma station reports much need of investigation in agricultural economics, practically no work having been done in this line in the State. Studies of crow control are of great importance, as the crow is protected in Kansas and Nebraska, and it is estimated that the cost of supporting it in Oklahoma runs into millions of dollars per year; potato investigations are badly needed; also studies of melon diseases; feeding investigations should be very much enlarged, there being a great demand for knowledge along this line. Practically nothing is known concerning the soils of the State, and greenhouse investigations should be carried on with proper chemical analyses to provide definite information as to their fertilizer requirements; crop rotation systems should be investigated, especially in the cotton-growing section; drainage and erosion studies demand attention; a great many problems should be taken up, including plant assimilation, the movement of plant food in soils, plant physiology, and soil acidity; the problem of the tight clay or hardpan, which occurs over most of the State, is no nearer solution than it was 40 years ago. Lack of funds has brought the station work nearly to a standstill.

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The Oregon station reports that no other lines of station work are more widely in demand than those relating to farm crops, including crop improvement, tillage methods, and crop rotations for Oregon conditions, weed control, and the establishment and maintenance of pastures. Facilities should be increased if the station is to meet the complex and important soil problems of the State. In dairying there are many problems of production and marketing upon which further information is needed, as well as investigations relative to feeds and feeding. There are urgent requests for investigations on the control of insect pests of the yellow pine; the pear thrip is proving very destructive and should receive attention, also the control of the alfalfa weevil. The station has no staff member and no provision for cost of production studies. Important investigations in the problems of feeds, feeding houses, and general management of poultry must be deferred until additional funds are available.

At the Pennsylvania station, among the various lines of investigation that should be taken up are studies relative to methods of maintaining and improving pasture lands of the State; the cause of abandoned farms and unproductive soils in the vicinity of manufacturing plants; the cost of production of farm crops; animals and animal products; culture, feeding, and development; several important plant diseases; protein requirements for the growth of dairy calves; feeding of home-grown rations to dairy cows; studies of ice cream, of special interest to the manufacturer; factors influencing the activity of Azotobacter in the soil; and the control of the tobacco hornworm and flea beetles.

The South Carolina station emphasizes the necessity for further investigations in regard to the value of southern crops in producing pork, with special reference to the avoidance of soft pork. Further studies are needed with grass and forage crops, and methods of developing pastures for beef cattle, especially the utilization of large areas of waste lands along streams and also of cut-over pine lands. South Carolina spends $50,000,000 a year for fertilizers, and studies should be made on the effect of different fertilizers on crops when applied to the various soil types of the State.

Among the various problems needing investigation at the South Dakota station may be mentioned those in crop pathology, forage crops in rotation, and permanent pastures; relation of sulphur in wool to the quality of the feed of the animal; enlargement of the operations in establishing hardy fruits for the Northwest; studies of the harmful and beneficial rodents and birds of the State; bee culture; cutworm control; fruit insects; and the insect parasites of domestic animals.

The Tennessee station reports that on account of lack of funds it will have for the coming year no horticulturist, no biologist, no veterinarian, and no meteorologist, and that work in animal husbandry has been cut to a minimum, although there are important demands in the State for information in all of these departments.

At the Virginia station work of all departments is suffering severely from lack of funds. Experiments along the lines of animal industry are inadequate and nothing is being done on animal diseases or in entomology. There is great need for investigation along the line of the economics of farming.

A large number of projects that should receive attention are mentioned by the Washington station, including the pocket gopher, field mice, and other destructive rodents; wilt diseases of forage crops; pasture studies; reclamation of alkali and tide lands; management of marsh soils; plant-food problems on cut-over land; water requirements of plants; horticultural by-products; the biennial fruiting of apples; strawberry and grape culture; various plant disease and insects; vegetable-seed production; degeneration diseases of potatoes; preparation of vegetables for storage; feeding work horses; range management; sheep diseases; factors affecting incubation and breeding of poultry; poultry housing under different climatic conditions; feeding problems of mature birds; cost of producing capons; alfalfa hays for milk production; standardization of ice creams and ice-cream mixtures; udder diseases; land drainage and farm-tractor power; cost of production studies with beef cattle, hogs, and sheep; farm leases and land tenure.

In West Virginia, the following projects demand attention: Value of buckwheat and fish meal as pork producers; buckwheat as part of the grain ration for breeding ewes; comparison of sunflower silage with corn silage for breeding ewes, two-year-old steers, and for milk production; pasture-improvement experiments; value of soy-bean hay and corn silage with home-grown grain; bacterial studies in cottage-cheese manufacture; the influence of a liberal supply of protein and ash constituents of animal origin in a ration for growing chickens as affecting the later fecundity of the females; the effect on the vitality of the embryo of holding eggs at various temperatures prior to incubation; bumble foot in poultry; infectious ophthalmia in cattle; social factors in rural community life; farm cost accounting; fertility experiments with truck crops; cultural experiments with apple trees; rôle of sulphur in vegetable crops; a study of hardy perennials and ornamentals; beekeeping; and fly control.

The subjects on which investigation is needed but wait on necessary funds at the Wyoming station are range investigations along both animal husbandry and agronomy lines; life-cycle studies of the sheep tapeworm; detailed studies of the common sagebrush, with reference

to feed value and products obtained by destructive distillation; a study of the therapeutic effect of drugs from typical poisonous plants; plant breeding; soil investigations; and the water requirements of Wyoming crops.

SOME RESULTS OF STATION WORK.

The work of the experiment stations has covered a wide range of subjects related to agriculture, and considerable progress has been made in many of them. A summary of some of the more outstanding results obtained is presented in the following pages:

AGRICULTURAL CHEMISTRY.

Studies in the relation of climatic conditions to the composition of cotton seed, at the Alabama station, show that a high rainfall in June, July, and August is accompanied by a high oil content. The North Carolina station finds that the toxic action of cotton seed, as a feed, can probably be overcome by heating with water, without the addition of any foreign material. An examination of Sudan grass for the presence of hydrocyanic acid, at the Kansas station, showed that if the grass is dried rapidly in the sun the poison can generally be found. After frost it soon disappears. The occasional cases of poisoning from Sudan grass are apparently due to liberation of the poison in the stomach through the action of an enzym which is very sensitive to the condition of the animal.

Investigations on the changes in composition of silage during fermentation, at the Iowa station, show that the total acidity, alcohol, and sugar, are entirely independent of the starch content of the silage corn, which remains constant throughout the fermentation process.

Chemical studies on the changes in composition of frosted wheat, at the Montana station, showed an increase in the nonprotein nitrogen, reducing sugars, and acid-reacting constituents. Milling and baking tests demonstrated the practicability of making good bread from prematurely frozen wheat. The Minnesota station finds that the glutens of flour are decidedly altered by drying, so that the difference between strong and weak glutens is then much less marked. Grain intended for seed should be stored in well-ventilated houses, while that which is intended for flour should not be ventilated. Extensive tests at the North Dakota station have shown that the true value of wheat for food purposes can not be determined by the physical characteristics that can be seen and sensed, nor has chemical analysis proved to be a true basis, although in many cases an increase in the nitrogen content of the wheat gives an increase in the volume of the loaf. The only basis appears to be the baking test. In a study of

substitutes, it is found that if more than 3 or 4 per cent of potato flour is added to wheat flour the volume, texture, and color of the loaf are noticeably lowered.

Much attention has been given to poisonous plants. At the Wyoming station the woody aster has been found to be most poisonous during the early stages of growth. The toxic principle has been isolated and is found to be neutralized by sodium carbonate, which indicates a possible treatment, but the practicability of such a remedy on the range is doubtful. Other poisonous plants which have been studied are the larkspurs, arrow grass, and lupines, all of which contain toxic principles, many having been isolated. Two larkspur species, *D. geyeri* and *D. barbeyi*, representing extreme habitats, were found to be quite closely linked from a chemical and physiological standpoint. The Colorado station has found a toxic glucosid in the whorled milkweed, most abundant in the leaves when the plants are coming into bloom. It is as poisonous when dry as in the green state.

The effect of alkali on Portland cement has been investigated at the Wyoming station, which finds that certain salts have an injurious effect, although acting rather slowly. Mixing the cement with weak sulphuric acid increased the alkali-resisting quality.

The peroxidase reaction has been found, by the Kentucky station, to be of value in seed-testing laboratories, for detecting nonviable seed, and for distinguishing between seed of high, medium, and low viability.

BOTANY AND PLANT PHYSIOLOGY.

The New Hampshire station, in a study of the growth of cereals, finds that there is not enough reserve of potash in the seed for normal growth and the symptoms of potash starvation appear early, the older leaves succumbing first, but the relative distribution of this element in the tops and roots is not affected by the quantity available. When potash-starved plants are supplied with the element, it promptly becomes distributed in accordance with the physiological needs of the plant. The amount of potash contained in a seed does not determine the length of time a plant grown from it can live in the absence of potash without injury resulting.

Studies on the nutrition of the fungus *Sclerotinia cinerea*, at the Minnesota station, confirm the theory that some substance similar to the water-soluble vitamin of animal nutrition is necessary for the normal development of the fungus. This vitamin is found to occur in considerable quantity in the juice of plums, peaches, and apples, in the sporophores of other fungi, in pollen and yeast, and its presence has been demonstrated in a great variety of other plant and animal tissues. There is some evidence of the necessity of two vitamins, one for vegetative growth and one for reproduction. The possible re-

lation of the vitamin content of the fruit tissue to disease resistance opens up an interesting field.

Studies of the permeability of plant tissues in the peach, at the Delaware station, show that the use of commercial fertilizers, in different combinations and amounts, results in a variable and selective permeability, not only toward salts used as fertilizers but toward other salts and organic compounds found in the tissues themselves.

The seasonal changes in most of the constitutents of fruit spurs are shown by the Missouri station to be distinct and characteristic of bearing, nonbearing, and sterile spurs. High starch and low nitrogen content at the time of fruit bud differentiation appear to be essential for productivity. Fruit-bearing spurs that develop leaf buds have a low starch and high nitrogen content and sterile spurs have a low starch and low nitrogen content. During the late summer and fall there is a steady increase in the phosphorus and nitrogen content of spurs with fruit buds, and the absence of this feature in sterile spurs suggests the necessity of the storage of these elements, preparatory to their marked increase, which is peculiar to bearing spurs in the spring, the fruit bearing of the spurs seeming to be dependent on this storage.

Investigations on the magnesium and sulphur nutrition of plants, at the Arkansas station, show that the oxid and carbonate of magnesium have a slight tendency to increase the oil content of the peanut and soy bean. Magnesium can replace the calcium in the leaves to quite an extent. It is also found that sulphur tends to increase slightly the protein content of the soy-bean plant.

Seed studies at the Michigan station showed the amount of combined water in some cases ran as high as 50 per cent of the weight, and the amount of water-soluble matter in dry seeds sometimes ran as high as 25,000 parts per million, apparently mostly protein. The Delaware station finds that the vigor, productivity, and food content of corn is quite closely related to reduction and oxidation processes of an enzymatic nature. A study of the nitrogen of legumes as cut for hay, at the Oregon station, showed that 30 per cent of the nitrogen in alfalfa is nonprotein, and of this, 10 per cent is amid nitrogen, 30 per cent amino acid nitrogen, and 60 per cent nonamino acid nitrogen.

BACTERIOLOGY.

Studies on the effect of woods and forest products on the bacterial activities in soils, at the Idaho station, showed that sawdust is toxic, cedar sawdust being most injurious and maple and ash least. All conifers showed an inhibitory action upon the nitrogen-fixing powers of the soil organisms. The addition of calcium carbonate to the forest soils improved conditions for nitrifying, ammonifying, and nitrogen-fixing organisms. Different species of soil bacteria were

found, by the Montana station, to vary largely in their response to arsenic, in forms used for insecticidal purposes, some of which compounds will kill most species outright, if applied in considerable strength, or if applied weaker, will inhibit or retard some of the normal physiological functions.

A study by the Colorado station of the natural inoculation of Colorado soils with legume bacteria, indicates this to be the case with alfalfa, sweet clover, and vetch, but that artificial inoculations are necessary for peas, beans, alsike, red clover, and white clover. The North Carolina station finds two distinct groups of organisms in the nodules of legumes. Eight distinct strains of *Bacillus radicicola* have been isolated from a number of native wild legumes of the State, by the North Dakota station. Indications are found by the Ohio station that nitrogen-gathering bacteria act in virtue of their ability to immobilize nitrate nitrogen by gaining the upper hand over the denitrifiers, rather than as active nitrogen gatherers. The New York Cornell station reports that certain algæ may fix amounts of nitrogen comparable with or larger than Azotobacter, provided nitrates are present; in the absence of nitrates, however, they apparently do not do this.

Chlorin, as chlorin water, was found, by the Arkansas station, to be rather effective against pathogenic organisms in milk, in concentrations that do not affect the odor or taste. Rats fed with milk so treated did slightly better than those on untreated milk. The Massachusetts station finds that the organisms occurring in canned peas, asparagus, and spinach are similar but not identical with *B. subtilis*. They can live with or without oxygen.

Studies on sterilization by pressure, at the West Virginia station, show that pressure up to 200,000 pounds per square inch is effective, and that the most delicate animal and vegetable material is not injured thereby.

GENETICS.

About 50 hereditary characters have been found in corn by the Connecticut State station, about half of which have been definitely located relative to the chromosomes. The New York Cornell station finds 8 distinct groups of characters, involving 20 or more factors, the factors within any linkage group being inherited more or less together but independently of those of other groups. In Blackhull White kafir the Oklahoma station finds 14 characters, some of which are units and some linked. Constant selection is necessary to hold them and the environment of the plant seems to influence all of the characteristics materially.

Important contributions in genetics have been made by the California station through studies of inheritance in tobacco, the work

being quite technical, but contributing important facts of general application. Crosses between a durum wheat and one of the common forms of emmer at the New York Cornell station have produced forms resembling the wild wheat or emmer of Palestine.

In a study of inheritance of characters in the apple by the Idaho station it was found that the color pattern of Ben Davis is dominant in all its crosses, while the tree characteristics of Wagner are also dominant.

In genetic studies with orthoptera of the genus Apotettix, at the Kansas station, as many as four different characters have been linked in a single individual so as to breed true, following strictly Mendelian segregation. It is believed that the same principles may be applied in the production of dual purpose breeds of cattle.

The Maine station, in studies on the inheritance of milk yield, has shown that high yield may be transmitted by either sex, that high yield is dominant to low yield, and that low butterfat percentage is recessive to high butterfat percentage. The inheritance of short ears in sheep has been investigated by the New Hampshire station by inbreeding short-eared animals, by which an earless strain was finally obtained. The presence of the short-ear character in one and of the no-ear character in the other parent gave lambs with short ears, but when the short-ear character was present in both parents an animal with no ears was produced.

It has been established by the Rhode Island station that egg weight is definitely inherited, and it should be possible to maintain a flock of hens laying eggs of uniform size by hatching chicks only from eggs of the desired type. The Maine station has shown that the linkage of egg production with the barred color pattern of the feathers in Barred Plymouth Rocks indicates a method of culling based on the feather color.

SOILS.

Studies on soil acidity at the West Virginia station show that for most field crops the optimum reaction is just below neutrality and that the harmful effect of soil acidity is due more to its depressing effect on the soil organisms than on the plant itself. Germination of the seed is less sensitive to acidity than subsequent growth. No relation was found to exist between the method of origin, the mineral composition, or the organic content of the soil and the intensity of their acidity. Heating increases the intensity of the acidity up to a certain temperature and then decreases it. Grinding decreases it in most soils, and it increases with decreasing moisture content. In general, the effect of organic decay is to decrease acidity.

The Oregon station finds that certain acid soils do not respond to liming as measured by crop growth. This was found to be due to

lack of phosphorus, the addition of which increased nitrification and ɪrrected the condition. A study of the hydrogen-ion concentration solutions used for growing plants, at the Maryland station, showed ıat this is not a factor in plant development, no correlation of this ith the growth being found.

Soil acidity studies at the Indiana station indicate that aluminum a greater factor in causing toxicity than the hydrogen-ion concen-ation, and the addition of available phosphorus tends to lower the idity by throwing the aluminum out of solution. The Michigan ation finds that soils which react acid or alkaline to litmus fall into ro groups, determined by the relation of the lime to the iron and uminum. In all acid soils this relation was found to be above : 1.3, while in all alkaline soils it was below this, 1 : 1.3 being the eutral ratio. The quantity of lime required to neutralize an acid il may be determined by computing the amount of calcium oxid ecessary to add to the acid-soluble calcium oxid in the soil to bring ıe ratio $CaO : Fe_2O_3 + Al_2O_3$ to 1 : 1.3. Studies on the use of ypsum at the Iowa station show that it has practically no effect ı soil acidity and does not serve to replace lime.

Experiments at the Rhode Island station confirm previous results, ıat a high-magnesium limestone may be used as profitably as other rms of lime for correcting soil acidity. The Pennsylvania station ıds that limestone, burned lime, and hydrated lime after two years ıve practically the same yields when used in equivalent amounts. one of the three forms showed downward movement sufficient to ɪrrect acidity below the harrowed 3 inches of the soil. At the Rhode land station corn made a rather chlorotic and abnormal growth here ground limestone had been added in large amounts, except hen used in connection with Thomas slag phosphate, which contains uch iron, or with large amounts of acid phosphate, which might aid the assimilation of iron. The results indicate strikingly the dele-rious effects of liming beyond the needs of a crop.

Investigations at the Oklahoma station on the effect of lime and anure on the impervious Kirkland upland soil, which comprises ɔout 50 per cent of the State and which has a hardpan about $2\frac{1}{2}$ et thick under 8 to 12 inches of surface soil, showed that the roots alfalfa, with no treatment, did not penetrate the hardpan, with ne alone they went nearly through, with manure alone they pene-ated through to the porous soils below, and with both treatments ɔing still deeper. The lime itself did not move down into the ırdpan. The treatment also stimulated the action of the ammoni-ing organisms and increased the development of the nitrifying ıcilli. The application of manure increased the moisture in the il, the effect lasting three years.

Analysis of a large number of Kentucky soils, by the station, showed that the best types contained the highest content of lime, the poorest having the lowest percentage. Cultivated soils showed considerably less lime than virgin soils. The application to low-calcium soils of a ton of limestone or rock phosphate per acre frequently adds more than is already present.

In extensive studies on the action and toxicity of soil alkali, at the Utah station, it was found that sodium chlorid and calcium and other sulphates first act in a stimulating manner, apparently connected with their effect on bacterial activity, through which nitrogen and phosphorus are made available. The favorable action of gypsum was found to rest largely on its chemical action on the soil constituents, especially iron and sodium chlorid. Chlorids and carbonates were most toxic, but this varied with conditions, carbonates being only half as toxic in sand as in loam. Organic matter tended to reduce the toxicity. Sagebrush is very susceptible to alkali and is a good indicator of its absence.

Attempts to reclaim alkali land by flooding, at the California station, showed that the drainage water was not taking off much of the black alkali (sodium carbonate). Chlorids and nitrates were found to rise faster by capillarity than black alkali. Conclusions reached on the management of black-alkali soils are that leaching is ineffectual as a means of washing black alkali from the soil. Large amounts of nitrates occur in the alkali, but always associated with still larger amounts of chlorids and sometimes of carbonates and sulphates. Toxic conditions are produced in such soils merely by adding sodium or magnesium salts, followed by leaching. In some cases, after removing the soluble salts by leaching, crops still made an extremely poor growth. Magnesium salts were more injurious than sodium, although the former leaves the soil fairly well flocculated, while the latter produces extreme deflocculation. Calcium salts, on the other hand, even when thoroughly leached from the soil, leave it in a condition highly suitable to the growth of plants. The Arizona station finds that 0.25 per cent of black alkali is near the limit for wheat, this amount diminishing the growth markedly. The limit, however, varies somewhat with the soil.

The results of five years' experiments with fertilizers in rotations at the Iowa station, show that manure increased the corn yield 25 bushels per acre, and acid phosphate gave a further increase of 15 bushels. Similar gains were made with wheat, oats, and alfalfa. Soils at the West Virginia station, which had received heavy applications of fertilizer for 13 years, but none for the past 5 years, are still showing marked residual effects, especially those plats which had received acid phosphate, which are still producing twice as much

owpea hay as the untreated plats. The Massachusetts station finds ıat ammonium sulphate may produce toxic compounds of manga- ese, aluminum, and iron, if these are present in the soil, and cause chlorotic condition in the plant growth, but that abundant rains ill leach them out.

Soil studies at the Michigan station show that soils may be cooled) $-4°$ C. and muck and peat to $-6°$ and $-8°$ without freezing. The mount of combined water in soils was found to be quite definite and ot to vary with the moisture content. When water is added to a ›il, some of it combines as water not containing any soluble salts, ıe result being a concentration of the salts in the soil sloution. In ›ils in a fine state of subdivision, the solubility in water is quite igh at a temperature of 52° C., diminishing below this. Quartz ıd quartzites give the highest solubility at this temperature of any f the soil minerals. The addition of various salts to the solvent oes not increase the solubility much.

Studies on the effect of fertilizer salts on the composition of the ›il extract, showed that the silica in alkali soils is more soluble than ıat of acid soils. The solubility of the phosphorus was increased y practically all of the salts tried, and there was also a tendency to ee sulphur. The amount of lime in the extract was increased by l of the materials tried, and this was true of the manganese to some xtent. Iron, aluminum, potassium, and calcium salts increased the mount of sodium in the extracts, and the general effect of the salts ied (except those of potash) was to decrease the solubilty of the ›il potash.

A study of the relation of soil moisture to balanced fertilizer ıtions, at the New Jersey station, showed no change in the physio- gical balance of the salts with different amounts of water, with the ıme amount of fertilizer, but by changing the amount of water ıere was a change in balance, resulting from a change in the con- ntration of the soil solution.

Investigations on the water requirements of various farm crops the Washington station showed that the value of summer fallow es not so much in conserving moisture as in making plant food vailable.

The Arkansas station finds that the ratio of carbon to organic atter in soils, may vary from 28 to 56, the general average being uch below 58, which is usually taken as the conversion factor.

Some evidence is being obtained at the California station that een algæ were responsible for nitrogen fixation on the surface of the ırth, in the first instance, and it is therefore probable that these, ıther than Azotobacter, were among the earliest living inhabitants the earth's surface. Experiments at the Montana station on the fect on nitrogen fixation of adding various salts showed that they

had but little influence in rich soils, but in poor soils the addition of phosphates was accompanied by an increase in nitrates, showing that they served a double purpose, acting as a direct plant food and as a stimulant to bacterial action whereby nitrogen may be oxidized and converted into nitrates. The largest increase in nitrates appeared in the continuously cultivated soils, the next largest being in the cultivated and summer fallowed soils, and the least in bare fallowed land.

A study on nitrates in soils, at the Missouri station, showed the crop to be the main factor in their removal. Early spring tillage increases the nitrates and a straw mulch of 10 or 12 inches practically inhibits their formation. The New York Cornell station finds that clover not only causes a larger increase in following crops than does timothy, but it leaves a larger amount of nitrate nitrogen in the soil, apparently having an accelerating effect on nitrification or contributing some easily nitrifiable material, although clover leaves the soil poorer in total nitrogen than some other crops. Plowing under large amounts of straw was found by the Washington station to depress the nitrogen content of the soil.

Studies at the California station, on the nitrogen nutrition of plants, showed that applications of nitrate of soda or sulphate of ammonia to soils deficient in available nitrogen, at certain stages in the growth of wheat, especially six or eight weeks after planting, is most effective in determining the gluten content of the grain.

Investigations at the Ohio station on the combinations and availability of phosphorus in soils shows that on an average one-third of this element in the surface soil and one-fifth in the subsoil, both virgin and cultivated, is in organic form, although there are large variations in the actual amount present in different soils. The reaction of the soil appears to be without influence on its quantity and nature. The phosphorus in this form is appraently not of a very high order of availability. It seems to bear a rather close relationship to the total organic matter and nitrogen. The Texas station finds that, as a rule, the phosphoric acid in surface soil is more available than that of subsoils and more so in nonacid than in acid soils. The phosphoric acid naturally contained in the Coastal Plains soil as found by the North Carolina station, is more available and acts more efficiently than that in either the Piedmont or mountain soils. The limiting factor for profitable crop yields on peat soils is found to be lime.

The Wisconsin station reports that a study of the rôle that iron plays in relation to the phosphorus shows that as the amount of iron increases there is also an increase in the amount of basic phosphate, with a decrease in the crop. There are indications that the presence of lime prevents the phosphoric acid from going completely

ver into iron phosphate. The addition of large quantities of acid hosphate did not increase the soil acidity, which is probably explained by the action of iron oxid, which is present in practically all oils.

Tests at the Illinois station show that plants are able to secure beral amounts of potash from the shales, from deposits recently disovered in Union County. At the Maryland station, by composting reensand marl with manure and sulphur, 40 per cent of the potash as made available, but considerable acidity was developed. The hio station has made a study of the tendency of fertilizers and lime increase the solubility of soil potash and also the effect of cropping on its availability, and concludes that while various treatments ave little direct action on the potash-bearing minerals, favorable onditions for crop growth result, thus depleting the available supply. he soluble potash content of unfertilized soils is greater than that f soils where the treatment has caused increased yields. The lichigan station reports that the fixation of potash in soils is related the calcium and magnesium and is the result of a chemical reacon. After leaching the fixation of potash is much diminished. he Tennessee station also finds by means of lysimeter studies that ere is not only no liberation of soil potash by lime and magnesium, ut that light, medium, and heavy applications of the carbonates ffected a depression of the potash outgo.

Studies on soil sulphur, at the Tennessee station, show that magneum salts cause a large increase in the formation and elimination of lphates. Both elemental sulphur and iron sulphid readily oxidize sulphates in the soil, without the aid of bacteria, and it is believed at the continued use of dolomitic limestone might eventually so eplete the soil of sulphur that it would become the limiting factor in lant growth. At the Ohio station applications of sulphur gave no dications that it increased the yield, but it did increase the acidity nd the solubility of certain mineral constituents. Oxidation of soil lphur was found, by the Michigan station, to go on most rapidly at 8° to 20° C. A small amount of sulphur, either elemental or comined, greatly stimulates the decomposition of peat and muck soils.

The California station finds that climate exerts a strong influence in odifying the soil flora, as was shown by studies of the same sample f the soil in different States. Methods of soil treatment also exert a arked influence, as shown by the Delaware station. The effect of maure is not always favorable, especially when applied shortly before lanting, when it lowers the nitrates and increases molds and other detriental organisms. The ammonifiers are increased largely by manure; e nitrifiers more by lime and phosphorus. An abnormal flora tends to duce the yields of hay, clover, and grains. At the Missouri station mples of soils exposed to the sunlight and others stored for two

years in the dark both contained *B. radicicola* and produced nodules with legumes. Studies at the Utah station of bacterial activity show that this extends several feet into the soil, diminishing with the depth. The optimum moisture for ammonification was 60 per cent of the water-holding capacity of the soil, for nitrification 55 per cent, and for nitrogen fixation 70 per cent. Examination of a large number of soils by the Kansas station showed that only about 50 per cent contained Azotobacter and that this was associated with the absolute reaction. Soils in which the hydrogen-ion concentration was greater than 1×10^{-6} contained none, but if the acidity was neutralized it was readily introduced and established by inoculation.

The Mississippi station finds that there is a direct relation between the bacterial count and the amount of green-manure material added to a soil. The cumulative effect of the latter is marked. In one instance 8 tons of oat and vetch straw produced a larger crop than 20 tons of fresh horse manure. The Michigan station finds that Actinomycetes are largely reponsible for breaking down the cellulose of composted peat. Studies at the Massachusetts station show that tobacco not only reaches its best development on soils of medium lime requirement, but "tobacco-sick" soils infected with the Thielavia root-rot organism can be corrected by increasing the acidity.

The soil survey in Iowa has been supplemented by chemical analysis, pot and field experiments with each type of soil, and a careful record of practical results. Many farmers have applied the recommendations based upon these results, and reports show that in many cases the red-clover crop has been doubled or tripled by the use of manure, limestone, and a phosphate. Corn yields have frequently been increased to the extent of 10 to 20 bushels per acre, wheat shows increased yields on many soils that are very profitable, and the same results have been secured from other crops, as oats and alfalfa.

FERTILIZERS.

In connection with the great increase in the use of commercial fertilizers in Arkansas during the past year, the commercial authorities recognized the leadership of the experiment station and agreed to instruct the salesmen to advocate the use of such fertilizers as the experimental results indicated.

A study of the effects of weathering and storing on manure, at the Missouri station, showed the loss due to leaching is mainly in potash rather than nitrogen, the loss of the latter being more in the gases given off. The New York State station has been conducting experiments in composting manure with various substances, including straw, peat, rock phosphate, acid phosphate, and gypsum, and finds that a considerable loss of organic matter and nitrogen takes place

xcept with the use of acid phosphate on peat. In culture experi-ents with these materials, using barley, fresh manure gave the best results, with the peat and acid phosphate composts next. Straw otted with manure gave about the same results as rotted manure one, the straw showing neither detrimental nor beneficial effects.

The value of applying sulphur with rock phosphate, if the mixture inoculated with sulfofying bacteria, has been demonstrated by ie Iowa station. The Michigan station finds that under anaerobic onditions a large percentage of rock phosphate can be rendered soluble hen composted with peat and a small amount of barnyard manure an inoculant. At the Georgia station raw rock phosphate com-osted with cottonseed meal gave a maximum availability in six eeks amounting to 3 to 5 per cent, but there was a loss of nitrogen ammonia that offset the gain in phosphorus availability. Com-osting rock phosphate with sulphur, at the Virginia station, to nder the phosphoric acid available, while showing a considerable crease in solubility, does not appear to be practicable for farmers.

At the Arkansas station it was found that on an acid soil the rn plant utilized phosphoric acid applied as rock phosphate, while e addition of lime to such a soil reduced the availability. The eatest availability of the rock phosphate was secured in sandy loam ils, with the addition of manure. The Florida station finds that a rge proportion of the phosphoric acid applied in fertilizers is retained the upper 9 inches of the soil. Experiments at the Maine station ow that barium phosphate gives no increase in yield.

The Texas station notes a marked increase in foliage, growth, and eld in cotton from sulphur-treated plats.

Experiments have been conducted at the Maine station, on the ect of borax on potatoes, using varying amounts per acre, with and thout watering. It was found that watering had little or nothing do with the amount of injury. No normal plants were obtained pot cultures where fertilizers containing boron were applied, all owing in varying degrees one type of injury characterized by a ogressive drying out and death of the margins of the leaves, ginning at or near the tip of the older and lower leaves. Boron is found in the dead tissues. Similar bad effects were noted on ans, but very little on cereals and buckwheat. At the Indiana ation it was shown that even small amounts of boron in ferti-ers, drilled in the row with corn, injured the crop. From one half 4 pounds per acre reduced the yield, while 16 pounds of anhydrous rax broadcasted did no appreciable harm. Similar tests at the Ver-ont station showed that borax up to one half pound per acre was t toxic and that there was a difference in crops in regard to the ury.

FIELD CROPS.

As a result of experiments on corn, cotton, and other field crops, at the Arkansas station, the Arkansas Seed Growers' Association has been organized and a pure-seed law passed.

The Utah station reports that manure applied to sugar beets at the rate of 10 tons per acre, gave an increased yield of about 1 ton of beets to each ton of manure. With potatoes manured at the rate of 5 tons to the acre, the yield was increased nearly 13 bushels for each ton of manure, but where 40 tons were applied the increase was only 4.3 bushels per ton. Manure applied to wheat gave an increased yield of 2 bushels for each ton where 5 tons was applied, 1.13 bushels where 15 tons was applied, and 0.33 bushel with 40 tons, the results with oats being about the same as with wheat. An average of nine years' application of manure to corn gave an increase of 3.83 bushels of grain and 428 pounds of stover, and 1.61 bushels of grain with 214 pounds of stover, respectively, for each ton of manure, when 5 and 15 tons were applied to the land each year.

Rotation studies at the Texas station demonstrated the inadvisability of winter or spring cover crops under conditions subject to late winter or early spring drought, on account of the reduction of available surface moisture, rotations that include a summer legume being much better. On rotation plats that have been running for 12 years at the Oregon station, where manure has been added, there has been an increase of 1½ per cent of organic matter and 50 per cent increase in crop production. A cover crop introduced into a rotation of wheat and potatoes, at the Kansas station, gave excellent results. Sweet clover was harrowed in the wheat in the spring and later plowed under for the potatoes. At the Maryland station, by sowing 1[illegible] pounds of sweet clover per acre in March, between two crops of wheat in rotation, about 9 tons of green manure were secured by the first week of August, this being found to be better than sowing the sweet clover in the stubble in the fall.

The Nebraska station has made extensive studies on the water requirement of crops. In tests on a large number of varieties of corn, a difference in total water requirement was observed, but there was practically no difference when based on a unit of dry matter. Sorghums required as much water, per pound of dry matter, as corn, while sunflowers required one-third more water. Increase of fertility results in an increase in water requirement through the larger size of plants and greater dry weight. The water requirement decreases with an increase in the density of the soil solution, until an optimum density is reached. Plants grown in soils low in fertility require an increased amount of water.

A study of the lodging of small grains, at the Ohio station, showed ıat quality is correlated with this character, poor quality going ·ith stiff straw. Moisture and sunshine are also factors; with ıore of the latter, there is less lodging. A partial remedy would ›em to lie in thinner planting. Varieties that stool largely are apt) lodge. Potash had no apparent effect in stiffening the straw. At ıe Wyoming station, early seeding of wheat, oats, and barley ave the best returns. Although the growth is slow at first they pen earlier than later seedings. Barley has proved to be among ıe highest yielding and most profitable of the spring grains, at the ebraska station. The California station has been instrumental in ıe introduction of Mariout barley, which exceeds in yield the common varieties at the station, and about 40,000 acres were grown the ıst year.

Much work has been done on wheat and a number of improved ırieties and strains have been developed. At the Pennsylvania ation, a superior selection, Pennsylvania 44, has been produced ıd is being widely planted, the demand for seed exceeding the ıpply. The North Dakota station has originated a variety, named Kota'' which is very promising as to yield, quality, and resistance rust. Two selections of wheat have been secured by the Missouri ation which are outyielding their parents by 8 bushels per acre. ıree valuable varieties, Gladden, Portage, and Trumbull, which ere originated at the Ohio station, continue to show increased elds and better quality of flour than the common varieties. Gladden now in its thirteenth year and 50,000 acres are now being grown the State, with 10,000 acres of each of the other two. Strains of ırkey Red wheat have been developed at the Nebraska station ıich yield 5½ bushels per acre more than the commonly grown ·ains.

The Washington station has developed some very heavy-yielding hybrids, both of wheat and oats and is endeavoring to develop ·ains that will combine this quality with smut resistance, some of ıich give great promise of being successful. A strain of wheat cured at the North Carolina station and now distributed yielded 4 bushels more per acre than other varieties tested. Promising sults are being obtained at the Maine station in selecting and veloping a strain of wheat that will retain its hard quality in that ate. Red Fife was found to produce the strongest flour and to ·e satisfactory yields. New and promising strains have been produced by hybridizing. A new and superior variety of durum wheat s been found by the Utah station, which has been named the evier.'' Kanred wheat, which was first distributed by the Kansas

station in 1915–16, now has an estimated planting of 500,000 acres. It is being still further improved for hardiness and disease resistance.

In continuous wheat-culture plats, at the Oklahoma station, those receiving manure yielded 23 bushels per acre, compared with 13 bushels on the unmanured plats. The relation of rainfall to yield is found to be in inverse ratio in June, a heavy fall giving a decreased yield. Wheat seeded in furrows outyielded that broadcasted, at the Kansas station, and for five years there has been an increase of nearly 5 bushels per acre with the furrows running north and south over those running east and west, accounted for by the difference in sunlight. Late seeding of spring wheat (April) gave 14 per cent more scab than early seeding at the Illinois station. Six years' trial as to the effect of thickness of stand of wheat, at the Nebraska station, show no change in production in abnormally thick plantings, nor are the weaker strains eliminated. Practically the same results were secured by planting one, three, or five plants to a hill.

The Wisconsin station finds that both root and stem growth of wheat cease beyond a certain range of temperature. Old roots of winter wheat are practically destroyed during the winter and a new system develops early in the spring. Normal growth was found to occur best at comparatively low temperatures. The inorganic nitrogen content of the plant is increased at higher temperatures.

Results of investigations at the Washington station point toward the possibility of improving the milling quality of wheat by increasing the nitrogen content of the soil. Cost of production studies at the North Dakota station showed that it cost $2.75 to produce a bushel of wheat in that State in 1919. It is estimated, by the Missouri station, that 6,000,000 bushels of wheat were destroyed by the Hessian fly in Missouri in 1916. In that year a force was put in the field to demonstrate and explain its control, and through the cooperation of the farmers the damage is now very much reduced.

Tests with oats, at the Maine station, showed that in the northern part of the State medium early varieities are superior in yield to the lighter early varieties. An early strain of Fulghum oats has been produced at the Kansas station, which is giving high yields and is being multiplied for distribution. The Nebraska station has secured a strain which gives an increase of 7 bushels per acre. High-yielding hybrids have also been produced at the Washington station. A new and improved variety named "Idamine" is ready for distribution by the Idaho station; and the Iowa station has a new variety, the "Iowar," which outyields other varieties by nearly 9 bushels per acre. In an average of five years' tests at this station, oats drilled in rows 6 and 8 inches apart have yielded about 3 bushels more per acre than when drilled 4 inches apart. The Arkansas station finds that rate, date, and method of seeding are all factors in getting

ood stand of winter oats, rate being the most important. Date of eding tests show the earliest safe planting to be the best for spring ats.

Cultural tests with buckwheat, at the Maine station, gave a larger ield by drilling than by broadcasting and less seed was required. n improved strain of sugar cane, Sc 12–4, developed at the Virgin lands station, is being widely grown there and in Porto Rico. The ation in the latter island is changing the varieties of cane generally lanted to those immune to mosaic. By rotating sugar cane with gumes, at the Louisiana station, using sweet and crimson clover, veet clover increased the yield of cane 6½ tons per acre.

A strain of alfalfa, bred by the Arizona station from a French ariety imported by the U. S. Department of Agriculture, has out-elded all other varieties, giving an especially high yield during the ot summer months. The West Virginia station has shown that eep and stony areas, too rough for cultivation, can be successfully eded to alfalfa, yielding satisfactory hay crops. Fall seeding of is crop gave the best results at the Tennessee station. The Kansas ation reports an increased yield of 1,000 pounds of alfalfa from an plication of 200 pounds of acid phosphate. Elemental sulphur was und to oxidize too slowly to be of immediate use for this crop, ich requires 40 to 50 pounds per acre per season, as shown by vestigations at the Washington station.

In a comparison of the relative value of alfalfa hay, cut at different ges of growth, at the Kansas station, the highest yield was obtained en cut in full bloom, giving 4.08 tons per acre. When cut in the d stage the yield was 3.43 tons, and the stand runs to weeds and asses in a very few years. The feeding value, however, was in favor the bud stage hay, calves fed on this making the most rapid ins and consuming the least hay per pound of gain. Those fed the hay cut in the seed stage made the smallest gains and con-med most hay per pound of gain.

The Tennessee station has been very successful in developing ains of Japan clover adapted to various purposes, as a tall, bushy riety for hay, a low growing, leafy variety for grazing, and one ich will withstand low temperatures for higher altitudes. It omises to become an important forage crop for the State. Interest the annual white sweet clover, which was developed by the Iowa tion, is rapidly increasing, both for a green manure and a pasture p. Growths of from 6 to 10 feet are reported from nearly all ts of the country. The best time for cutting vetch and wheat vetch seed the Maryland station finds to be about three weeks er the bulk of the crop is in bloom. The Illinois station has ablished the fact that the Lima bean bacteria are identical, for culation purposes, with the cowpea group.

Corn improvement work at the Virgin Islands station has resulted in large increases in yield in the island. The New Mexico station has produced and distributed a strain of Mexican June corn, good for either silage or grain, with a small cob, bearing two ears, having a tight husk which excludes worms and which yielded an average of 82 bushels per acre. Tests on the productiveness of different varieties of corn at the Connecticut Storrs station has resulted in the establishment of a seed-growing center for Century Dent corn at New Milford. Eureka corn is reported to have produced 20 tons of silage material per acre, containing 8 tons of dry matter. Rustler's White Dent corn, as selected and improved by the Idaho station, is having a marked influence on the corn production of the State. A variety of corn which has been named "All Dakota" has been produced at the South Dakota station, which it is believed will ultimately represent a combination of high yielding characters in varieties successfully grown in the State. A difference in yield of corn as high as 40 bushels per acre has been found among varieties grown on the same piece of land, at the Missouri station.

Studies on corn fertilizers, at the Missouri station, gave an average net return from an application of 8 tons of manure of $22.04, from each ton of limestone $6.08, from 300 pounds bone meal $25.46 from 400 pounds of acid phosphate $19.56, from 1,000 pounds of rock phosphate $2.17, and from 50 pounds of potash $2.35. Corn studies at the Virginia station show a significant relation between yield and length and average circumference of ear, average circumference of cob, shape of ear, trueness to type, character of tip uniformity and shape of kernels, and size of germ. The relation is slight between yield and ratio of butt to tip circumference, percentage of grain, number of rows, average length of kernel, character of butt and space between kernels and between rows. A four-year rotation of which three were in corn, has not proved very successful at the Illinois station. A comparison of the root systems of corn and sorghums by the Kansas station showed the latter to have twice as many small roots as the former, which enables it to withstand limited water supply much better.

The Kentucky station finds that sound corn with not more than 12 per cent of moisture is not likely to spoil, and meal made from such corn can be kept in a condition suitable for human consumption from four to six months, provided moisture and air are excluded. This point is of special importance in the export of corn in the hold of ships. The saving of soft corn by salting has been quite successful at the Illlinois station.

The Oklahoma station has developed an improved strain of cotton O-44, with a 1-inch staple and high yield, that is being distributed. Cotton breeding, selection, and hybridization, at the Virgin Islan

tation, has produced four improved strains of Sea Island cotton, vith exceptionally long staple and prolific bearers, one of which ppears to be resistant to the blister mite. The Alabama station stimates that more than 50,000 acres of cotton are now grown nnually from strains bred by the station, the reports from which how increased yield with a high percentage of lint, greater freedom rom bud rot, and increased uniformity and earliness. The New Iexico station has demonstrated that cotton can be successfully rown in the State and the acreage is rapidly increasing. The Durango type is best, long staple cotton not maturing, but it is hoped o develop a strain of Egyptian cotton that will mature. The verage yield for four years has been 1¼ bales of lint per acre.

Investigations as to the best method of growing cotton under oll-weevil conditions, at the Alabama station, showed that thick eeding, then harrowing the crop crosswise, leaving all the plants hich remain, gives the best yield, the plants being thick in spots, ausing early fruiting as a result of competition. Nitrate of soda was nore effective as a fertilizer than other sources of nitrogen. The Iissouri station secured a net profit of $8 per acre from moderate pplications of acid phosphate on cotton, 300 pounds giving 100 ounds increase in lint. The Georgia station reports that the optinum application of fertilizers for cotton varies from 600 pounds of n 8–3–2 fertilizer on heavy clay soils to 600 pounds of an 8–3–6 n sandy soils. Studies on place variation in cotton, at the North arolina station, carried on in cooperation with the Mississippi ation, show that the Mississippi seed of the same strain gives a rger yield, is earlier, with a larger number of bolls, taller plants, nd slightly longer lint than the North Carolina seed.

A study of the correlation of inherited characters in cotton, by the exas station, showed that a high oil content goes with large seed nd a low ginning percentage, the protein relation being in inverse atio, high oil content going with low protein. There is found to be ttle correlation with yield. Investigations at the Mississippi station n the amount of natural crossing in cotton showed this to be from to 8 per cent between adjacent rows and less than 1 per cent in ows separated by one other row of cotton.

Two strains of flax of high quality and resistant to wilt, have been red at the Minnesota station. The Virgin Islands station reports ery successful results in growing elephant or Napier grass, which as yielded 34 tons of green fodder per acre in 10 weeks' growth. is being widely distributed over the islands. Similar favorable sults are reported by the Porto Rico station. The Florida station as been quite successful in the introduction of Bahia grass in the ate. Improved strains of timothy have been secured by selection the New Hampshire station, and have been distributed.

At the Nevada station it is shown that in pasture lands drowned out by improper irrigation practices, the grasses change to worthless sedges, which can be corrected by adopting proper methods of irrigation. Studies on the effect of burning pastures, at the Kansas station, showed that while grass starts quicker after burning, there is not much difference at the end of the season, and there are less weeds in the unburned areas. Investigations at the New Mexico station have demonstrated the value of shadscale (*Atriplex canescens*) as an emergency range cattle feed. No bad effects were shown in cows kept on this pasture, although under certain conditions it is more or less poisonous to sheep. The Nevada station has found that sheep grazing on white sage should receive a supplement of from 2 to 4 ounces of concentrates (corn and cottonseed meal) per head. By this means, the loss of lambs was reduced 60 per cent. From 30 to 40 days' feeding is sufficient, and in favorable years it is unnecessary.

A number of poisonous range plants have been studied at the Nevada station, which has included feeding experiments to determine the lethal dose. This has included *Hordeum jubatum*, water hemlock, a milk weed, *Artemisia spinescens*, a Chrysothemus, three species of Solidago, two species of Tetradymia, several Delphiniums, aconite, and a Ranunculus. A saponin has been found in Atriplex which is poisonous to sheep at certain times, but not to cattle. Hydrocyanic acid has been found in arrow grass. The first tender shoots of the water hemlock (*Cicuta occidentalis*) are almost as poisonous as the roots, a few ounces being fatal. *Asclepias mexicana* is highly poisonous to sheep and cattle. Death camas is fatal only if eaten in large quantities, and causes but little loss. The results obtained by the Montana station in spraying with iron sulphate for the eradication of loco weed have been very satisfactory.

As a result of 10 years' work in potato breeding at the Utah station, selected seed has yielded 353 bushels per acre as compared with 184 bushels from unselected seed. At the Maryland station small seed pieces of the potato are found to produce spindling sprouts, the cause of which is not found to be evaporation, and chemical analysis does not show the removal of any definite substance in cutting that would account for it. It was also found that the addition of potato juice to a young potato plant acts toxic and diminishes the growth. After potato vines are killed by frost, unless the tops are cut off the big tubers become mothers for the little sets, which then develop at the expense of the big ones.

A study of the dormant period of potatoes, which lasts for about 90 days, during which they will not sprout, showed no change in composition during this period. The change from dormancy seems to be due to an exchange of gases, metabolic changes being at a standstill during this period. A study of the effect of using deformed

seed potatoes at the Colorado station indicates that it has little effect on the crop, the deformity being due chiefly to the ancestry of the tubers rather than to the condition of the individual seed piece. The Utah station finds that late plantings of the potato largely escape Rhizoctonia disease. Seed treatment with corrosive sublimate was effective for its control. It was found at the Wyoming station that the larger and fully developed plants gave the highest yields. Very little difference was noted between the stem and eye end of the tubers when used as seed. In spacing, the average weight of yield per hill increased directly as the distance apart of the hills in the row increased, but the total yield per acre was greatest with close planting, although the percentage of marketable tubers decreased.

A fertilizer low in potash produced the best seed potatoes at the Rhode Island station, but potato plats on which potash had been omitted entirely for 10 years yielded only 56 bushels of small tubers, whereas with a liberal amount of sulphate of potash the yield was 171 bushels. Tests at the New Jersey station show that the best time in the development to harvest the potato for seed is when approximately 50 per cent of the leaves were dead. Investigations at the Nebraska station indicate that under dry land conditions the yield of potatoes can be maintained for a long period if proper seed selection is practiced, while on the other hand the continued use of small potatoes, selected at random, reduces the yield. Potatoes that have been irrigated for one or more years show an increasingly higher percentage of degenerate strains.

Experiments at the New Mexico station have shown that the Irish potato is not a dependable crop in the lower and warmer portions of the State. A comparison of ordinary and cold-storage potatoes at the Rhode Island station showed very little difference in vitality. Tests of size and number of eyes in the seed piece showed that with the same number of stems, with the same amount of vines, the yield is not influenced by the size of the seed piece.

In experiments in storing sweet potatoes, at the Alabama station, it was found that a temperature of 25° F. did no harm to tubers that had been well cured by previous heating, but did to others. The loss of water in curing is about 4 per cent, the cured tubers being less corky, lumpy, and dry when cooked.

Extensive plantings of high land rice have followed its introduction by the Porto Rico station. In Louisiana about 3,000 acres of rice were seeded with varieties distributed by the station, with yields much above those obtained from varieties commonly grown. The demand for the improved seed exceeds the supply.

Tests of the rate of seeding soy beans with corn, for hogging off or for the silo, at the Indiana station, gave the best results from 5 to

8 pounds per acre. At the Missouri station a material growth of soy beans, by whatever method grown with corn, materially reduced the yield of the latter, except when planted late.

The Connecticut State station has developed a superior tobacco hybrid, a combination of Sumatra and Broadleaf, called "Connecticut Roundtip." Wide variations were obtained at the West Virginia station in the yield and quality of tobacco from different fertilizer treatments, manure and acid phosphate giving the highest net returns. Studies on the concentration of nitrate of soda tolerated by tobacco, at the Kentucky station, indicate that when this is greater than 1 part in 3,750 parts of water the plants wilt, but will recover from strengths up to 150 parts, above which growth was prevented and the plants die. Experiments in the curing of Burley tobacco show that as high grade leaf can be obtained by flue curing at a relatively low temperature as by air curing, thus eliminating completely the danger of house burning.

Montgomery seed-leaf tobacco, which was originated at the Ohio station, is now having a world-wide distribution.

HORTICULTURE.

Both the Maine and the Pennsylvania stations note that yield of apples is closely correlated with trunk circumference and more loosely with rapid growth, and that this measurement may also be taken as an index of the effect of fertilizers. The type of tree is also a factor in yield, which is true even within the same variety.

At the Ohio station, in fertilization experiments on apple orchards, in Washington County, nitrogen alone gave as good results as a complete fertilizer. Contrary to the general belief in the peach-growing sections of the State, applications of nitrogen not only did no harm but improved the yield. In a long series of experiments in orchard practice at the New Hampshire station, fertilized trees are just beginning to show increased yields over the unfertilized ones, after 12 or 14 years. When a nitrogenous fertilizer had been used the yield was 83 barrels of apples, with a combination of phosphorus and potash 50 barrels, and where no fertilizer had been applied 45 barrels.

Apple trees under tillage have done much better than untilled trees, and the value of this practice has been established. Clean cultivation is giving better results than cover crops in the orchard at the Illinois station. In a comparison of the advantages of mulching and cultivating at the Ohio station, the conclusion is reached that this depends on the soil and conditions, mulching giving better results on a dry soil. At the Indiana station, trees under tillage and cover crops made 45 per cent more growth and produced 11 times as much fruit as trees in sod. Tillage and straw mulch were superior

to grass mulch. In a young fruit orchard of apples, cherries, and plums at the New York Cornell station, cultivated trees grew better than those in sod, and fertilizers appeared to have no effect on the latter. There was found to be less soil moisture and less fixation of nitrogen in the sod plats. Good results were obtained in the renovation of prune orchards, at the Washington station, by the use of manure and cover crops.

Pruning was found to be a dwarfing process at the Indiana station, causing the trees to come into bearing later. The root system is found to be dwarfed even more than the tops. Lightly pruned trees made 48 per cent more growth than heavily pruned ones. The New York Cornell station also reports that any considerable amount of pruning reduces the leaf surface, delays fruiting, and reduces production. Similar results were obtained at the Massachusetts station, where improved trees made the largest growth in girth of trunk, which diminished with the amount of pruning. A comparison of trees pruned during the dormant period, in February and in June, at the Nebraska station, showed a greater rate of growth in the former. Pruning experiments at the California station have more or less revolutionized the practice in the State. Long pruning gave a much better growth of tree, with higher yields, in some cases from 50 to 100 per cent higher, than short pruning. Pruning by thinning out gave better results than heading back, the latter causing an abundance of sucker-like growth. Pruning studies at the Oregon station were directed to the effect on the physiological activities of the tree.

In apple pruning experiments at the New Jersey station, the pruned trees have yielded more and better fruit than the unpruned ones, and the beneficial effect on the general condition and shape is noticeable. Defoliation was found to disturb the carbohydrate-nitrogen ratio and to throw fruiting spurs into vegetative growth. A close correlation was found in certain varieties between the total leaf area removed and the size and quantity of fruit produced. Similar studies on the tomato showed that the fruit production in this plant is dependent on the carbohydrate-nitrogen supply of the whole plant and not of the fruiting spurs only, as in the apple. A severe removal of the foliage prevents the development of the fruit, even when blossoms are abundant. In the apple, the general appearance of the leaves was found to be a very good index of the vigor of the tree. Results obtained at the Virginia station confirm that of others, in that summer pruning of the apple retarded growth, delayed fruiting, and was especially harmful as regards fruit-bud formation.

A comparison of spraying and dusting, at the Virginia station, showed that dusting with mixtures of sulphur and lead arsenate was

effective for controlling curculio, codling moth, and peach scab, but it did not control bitter rot of apples and brown rot of the peach, and was of doubtful value in apple scab. Standard methods of spraying paid good dividends on the cost, even with the least efficient sprays, at the Maine station. At the Illinois station, a study of the cause of the drop in pressure between the pump and the nozzle in spray apparatus showed that this is greater the larger the nozzle opening, and that couplings also cause a loss.

Much progress has been made, at the South Dakota station, in securing new hardy varieties of fruit from the extreme north, to be used in developing hardy varieties for the Northwest by cross-pollination. Grape cuttings have been secured 200 miles farther north than had previously been reported.

The Arkansas station has definitely shown that the set of fruit depends largely on the vigor and abundance of the pollen, and that the size of the fruit is closely correlated with the number of well-developed seeds, which are, in turn, dependent on the abundance and vigor of the pollen. Plats receiving nitrogen showed a decided increase in pollen vigor. On plats with an excess of nitrogen the fruit was deficient in color. Fruit spurs were modified in vigor and performance by the general vigor of the branch and their position upon it.

Studies of factors affecting the setting of fruit of tomatoes, at the Oklahoma station, indicate that falling of the blossoms is due largely to imperfect pollination and that moisture is also a factor in the setting of the blossoms. The loss of peach buds during the winter is apparently due to a weakened condition and is a nutritional problem. High cultivation resulted in better development of fruit buds, especially with peaches, at the Virginia station, and also gave larger yields of fruit and better growth of trees than either low cultivation or sod.

Studies on fruit-bud formation under different systems of orchard management, at the Iowa station, indicate that apple trees on clover sod and on cultivated plats tend more toward annual bearing, while on the bluegrass-sod plats they are biennial bearers, which may be explained by the fact that the former made sufficient annual growth for the formation of fruit buds on the younger portion of the trees, the older fruit spurs being very irregular bearers. The studies indicate the possibility of producing annual bearing trees by proper orchard management. Investigations on the influence of light on fruit-bud formation, at the New Hampshire station, showed that in the shaded trees the leaf area was larger, but branching and fruit-bud formation was much less than trees growing in sunlight, which probably explains why dense unpruned trees do not flower in the interior of the tree. The Utah station finds that the amount of injury to

fruit buds by freezing is influenced by the concentration of the cell sap.

A very valuable hybrid of the dewberry and raspberry has been produced at the Texas station, with fruit of fine quality, which is self-fertile and which readily crosses with other species of Rubus. The fruit is larger than that of either parent, of a dark red color, and intermediate in flavor. June drop, which is very common in the State, was found by the Washington station to be due to incomplete fertilization.

Studies on winter injury at the Nebraska station show that as a rule the root system coming from the stock was killed, while that from the scion wood withstood freezing temperatures, the results suggesting the advisability of propagating fruit trees in such a way as to get the major portion of the root system from the scion wood. The investigation has brought out some interesting data as to the rooting habits of various varieties of apples, in some of which the scions root readily the first year, others requiring two or three years, and some not rooting at all. The handling of perishable berries by freezing has been quite successful at the California station.

Stock and scion studies with the apple, at the Massachusetts station, show that Oldenburg and Northern spy roots have a decided dwarfing effect. The Baldwin seems less hardy on its own roots than on some others. Results of a study of the factors influencing the biennial bearing of apples, at the Maryland station, show that a spur which blossoms but does not fruit will probably blossom again. If it does not set fruit up to the June drop, it will bear the next year. Two groups of blossoming spurs can be distinguished, one of which will blossom the next year, the other not. Those making the largest growth with the most leaf area blossom. Spurs which make a growth of 2 millimeters or less do not bloom, with 4 millimeters they bloom but do not set fruit, with 6 millimeters they bloom and set fruit, and longer ones become vegetative. Attempts are being made to control these by fertilization, pruning, and cultural methods.

The Delaware station finds a close relation between the health and vigor of apple trees and injury caused by spraying materials. . Spray injury symptoms can be used as an indicator of fertility starvation in apple orchards. In studies in apple storage at the Washington station it was found that the summer temperature had little influence, but the temperature at the time of maturity and during the harvesting of the fruit is very important.

Cowpeas proved to be the best cover crop in the citrus grove, at the Arizona station, and it was found to be good practice to sow alfalfa in the grove in the fall. The Florida station finds that the use of ground limestone and Thomas slag causes injury in the orange grove, indicated by frenching. Clean cultivation throughout the

year was of considerable benefit to young trees, but after a few years leads to a loss of soil nitrogen. It is not a desirable practice with trees over five or six years old. At the California station, a cross between a paper-rind orange and a grapefruit has been obtained, the result being a grapefruit with a very thin skin and a juicy, firm pulp.

Investigations on hardiness of the peach, at the Maryland station, show a marked seasonal increase in the water content of the fruit buds of certain varieties, the difference becoming more marked as the season advances. In those varieties considered the most hardy the ratio of water content to dry weight of fruit buds is less than in others. Nitrogen and potash gave striking results, both in growth and yield, in the peach orchard at the Alabama station.

The Arizona station is developing a species of tamarisk from northern Africa, which is very ornamental, of rapid growth, tolerant of strongly alkaline soils, and with hard and durable wood. At the Illinois station, applications of acid phosphate in the greenhouse gave about 5 per cent increase in flower production for two or three years without further applications.

A number of superior strains of beans which breed true have been isolated at the Maine station. These surpass in size, appearance, and yield, any now on the market. The Porto Rico station has been successful in its efforts to encourage a greater production of beans for home consumption. The importance of phosphorus in the fertilization of early cabbage on Hagerstown clay loam has been demonstrated by the Pennsylvania station, nitrogen, and to a larger extent potash, giving very slight returns, the results pointing the way to both better yields and more economical fertilization. Applications of 3,000 pounds of lime per acre, at the Rhode Island station, were successful in preventing club root of late cabbage following spring crops. The New Mexico station has produced an improved variety of chili (No. 9), which has a large, smooth, tapering pod, fleshy, and with no shoulder at the stem end. The Ohio station has developed strains of lettuce that are not very susceptible to tipburn, which has been giving considerable trouble in the State.

The Tennessee station has been very successful in developing a Fusarium-wilt resistant tomato. Grown on wilt-infected soil, 86 per cent of the plants were free from wilt and all matured a good crop. Selections have kept their resistance for 10 years. Similar successful results have been obtained at the Illinois station. Striking results have been obtained at the Missouri station, in fertilizing tomatoes. Phosphates gave the best returns, often doubling the yield and causing early maturity. The fertilization of tomatoes proved profitable at the Indiana station, 500 pounds of a 2–12–6 fertilizer giving a net profit of $44.45 per acre. Similar results were obtained at the New

Hampshire station, demonstrating the value of phosphorus for this plant.

Studies in metabolism in sweet corn, at the Maryland station, indicate that a distinction should be made between the ripening and maturing stage, the latter being a drying-out process. The total nitrogen and fiber early become quite constant, the principal changes after this being in the carbohydrates, in which the starch increases and the sugar falls off. The best edible period lasts only two or three days with the early varieties. The corn is ripe when the constituents have attained an equilibrium.

FORESTRY.

At the Iowa station, after 15 years of service, fence posts from common Iowa woods that were creosoted are still serviceable, while the same posts uncreosoted lasted only from three to five years. By this treatment the inferior, soft woods of the State can be used for this purpose. In a study of insects attacking freshly cut wood, especially pulpwood, at the Minnesota station, it was found that shading the logs during the summer will prevent the development of some species and the ovipositing of others. Logs that have been stored in water for a time are less subject to attack when removed from water and dried than those that are stored dry.

DISEASES OF PLANTS.

Promising results are being obtained at the Michigan station in the differentiation and determination of different strains and varieties of pathogenic fungi, especially Fusaria and Phoma, by the biologic test, in which rabbits are sensitized and the anaphylactic reaction noted. About 30 species of Fusaria that are often hard to distinguish, except by the biological method, attack potatoes.

The Wisconsin station finds that soil temperatures influence seedling infection with fungus and bacterial parasites, although the range is quite wide. Wheat seedlings are found to be subject to attack by the wheat-scab organism between 3° and 30° C. and corn is subject to attack at still lower temperatures. In studies of the relation of time of planting to disease, less disease was found on late-seeded winter wheat, early-sown spring wheat, and late-planted corn.

The Texas station has isolated the causal organism of the black mold of ear corn. Infection takes place only in the milk stage, and thin-husked varieties are most susceptible. The same fungus attacks other hosts, causing rots of squashes, peaches, and plums. In studies on the root and stalk rots of corn, at the Indiana station, the primary trouble was found to be, in many cases, an accumulation of metals, mainly iron and aluminum, in the nodes, which, in undergoing oxidation, destroy the normal conditions, weakening the roots

and rendering them susceptible to the attack of rot organisms. Limestone and acid phosphate applications appear to remedy it. Studies of corn root rot at the Missouri station show that seed is commonly infected, often in an apparently healthy ear. The Kentucky station finds that practically no seed grown in the section was free from infection with the organism causing this rot, *Fusarium moniliforme.* Infection was found to take place before the late milk stage and apparently occurs through the silk. Selection of resistant strains seems to be the only means of control and has been attended with some success.

A severe epidemic of corn rust on the breeding plats, at the New York Cornell station, showed that most North American varieties of dent, flint, flour, pop, and sweet corn are susceptible, while practically all of the South American varieties are highly resistant. The red-rot fungus of sugar cane (*Colletotrichum falcatum*) was found, by the Louisiana station, to be the principal cause of poor germination.

The Texas station reports that the cotton-wilt organism will attack okra, but a new okra Fusarium was found that will not attack cotton. A definite relation was found between temperature and wilt, the most favorable being likewise so for the host. With proper drainage good results were obtained in the control of Texas root rot as it affects cotton, by rotation and deep plowing. It has a large number of hosts. Temperature and moisture are the controlling factors. The successful control of angular leaf spot and anthracnose of cotton has been secured at the Arkansas station by delinting, and at the South Carolina station by keeping cotton seed three or four years before planting, the latter method now being quite generally practiced. The North Dakota station reports that evidence has accumulated that wilt resistance in flax is a permanent quality that may be transmitted and increased.

Studies of cereal leaf rust, at the Indiana station, show two distinct strains. The genus Thalictrum, of the Ranunculaceæ, appears to be the common alternate host in upper central Europe, but in this country the rust apparently lives over on wheat only. There is considerable variation in the resistance of varieties of wheat to this rust. It is specific and is not identical with any of the characteristic grass rusts, although several species of grasses and grains have been found on which it will grow weakly.

In breeding for resistance to stem rust in wheat, at the Minnesota station, hybrids have been obtained that are quite resistant to at least two biologic forms of the fungus, while neither of the parents were resistant to both.

The Idaho station finds that smut infection of wheat increases with increased moisture content of the soil at planting time. Culti-

vating summer fallow was found to increase the percentage of smut in the subsequent wheat crop.

The Iowa station reports that the Septoria leaf spot of wheat survives in the imperfect stage the period from harvest time until the rosette stage of winter wheat. Mature pycnidia were found in volunteer and winter wheat seedlings as early as October 2 and November 1, respectively.

The Virginia station finds that nematode disease of wheat may be controlled by the use of clean seed and crop rotation. Studies of wheat diseases at the North Dakota station, show that both Fusaria and Helminthosporium, a number of strains of which have been isolated, are commonly seed-borne, emphasizing the value of seed treatment and selection.

The Iowa station finds that crown rust of oats also attacks a large number of grasses in at least nine genera, on which it is probably carried over winter or which serve as intermediate hosts.

Investigations by the Maine station on the transmission of potato mosaic showed that this may be done by means of tubers, grafting, the plant juice, and aphids, but attempts to transmit it through flea beetles, potato bugs, the seed-cutting knife, contact of seed pieces, roots, and vines were unsuccessful. All indications are that it is a parasitic disease, and plant lice are evidently active agents in its spread. For its control, spraying for plant lice, early harvesting of potatoes intended for seed, and isolated seed plats for disease-free seed are recommended. Good success has attended efforts to produce seed free from the disease. Leaf roll is also a virus disease and is apparently transmitted by insects, and while it is more destructive than mosaic it does not spread so rapidly. There are indications that this disease and net necrosis are closely related if not phases of the same disease, as tubers with net necrosis are likely to produce plants with leaf roll, although the reverse is not true.

Studies on the viability of the potato blackleg organism indicate that in Maine the bacteria do not live over in the soil, due to the fact that they can not survive after being separated from the host plant. Spraying with Bordeaux mixture for the control of late blight of potatoes, at the New Hampshire station, indicated that used in amounts sufficient to supply about 25 pounds of metallic copper per acre, applied in weekly or fortnightly sprayings, the mixture gives absolute protection.

The Vermont station finds that potatoes grown in newly cleared land from disinfected seed, with artificial fertilizers only, give only about 2 per cent of scab, indicating that the organism occurs commonly in the soil. The New Jersey station reports that the use of elemental sulphur for the control of this disease, when applied at

the rate of 300 to 600 pounds per acre, more than doubled the percentage of clean tubers with some increase in yield.

Studies on the spread of Verticillium wilt through the soil, at the Oregon station, indicate that this is at least 15 inches in a single growing season. Its entrance in the host plant is apparently through the root and it seems to be commonly associated with Fusarium wilt. The Idaho station reports that in the control of Rhizoctonia disease of the potato by treating the seed with corrosive sublimate it is found that different amounts of this material are absorbed from the solution by different varieties of potatoes.

Speck or wildfire of tobacco is found by the North Carolina station to be carried over in the seed, the soil, and the cloth covers used on the tobacco beds. For the control of this disease, as well as angular leaf spot, the Virginia station obtained good results by sterilizing the seed with formaldehyde solution, sterilizing the cloth coverings, and locating the seed bed on new land, and the Kentucky station found an effective means of preventing infection was covering the seed pods from flowering time on. Studies on the control of root rot of tobacco, at the Ohio station, show that steaming the seed bed is the most practicable method. The bacterial blight of soy beans is found, by the North Carolina station, to be seed borne and that preventive measures lie in seed treatment.

Studies at the Maryland station on the control of Sclerotinia fruit rot, which also attacks buds and blossoms, show that dusting or spraying with lime sulphur and Bordeaux, if done early, will control it in the blossoms, after which there is not much trouble until the fruit gets ripe. The Delaware station finds fire blight is related to winter scald, which results from the exposure of the roots at the base of the trunk, from which varying degrees of sun scald and winter scald result. Banking the stems appears to reduce sun-scald injury.

In studies of apple diseases, the Oklahoma station found that three sprayings gave absolute control of blotch. These should begin as soon as the petals drop. Studies on this disease at the Indiana station showed that winter spraying with lime sulphur gave no control. Bordeaux dust gave 31 per cent of clean fruit, sulphur dust 53 per cent, and Bordeaux spray 60 per cent. For summer spray, however, lime sulphur was found to be about as good as Bordeaux. A prebloom spray of strong Bordeaux mixture was successful in controlling scab, at the Ohio station.

At the Iowa station, blister canker was well controlled, on hardy trees, by removing the infected portion with a gouge and mallet and painting the wounds with a lead paint containing 1 ounce of powdered mercury bichlorid to 2 quarts of paint, the bearing life of the trees being prolonged several years thereby. The Arkansas station finds that

ew trees may be planted in orchards where others have been killed by lister canker without danger of infection through the roots.

At the Virginia station, studies on the susceptibility of Northern py rootstocks to Xylaria, causing black rot, indicated that while they ossess a considerable degree of resistance and are superior in this espect to the ordinary seedling stock, they are not wholly immune o infection. Preliminary studies of the physiological characteristics nd behavior of varieties differing in susceptibility indicate that there a significant relation between carbohydrate transformation and usceptibility. Investigations on apple rust, at the West Virginia ation, show that leaves become immune in from 10 to 28 days from e time they unfold. The eradication of the red cedar has proved to e a very effective means of reducing the disease.

The New Jersey station reports perfect control of the cherry leaf pot by spraying with lime sulphur, like success being secured by the Visconsin station by proper sanitation, such as plowing under or disosing of the dead leaves, with two sprayings of Bordeaux or lime ulphur.

At the Florida station, all investigations have failed to give evidence at gummosis of citrus trees is due to any parasitic cause. A ausal organism of gummosis of the lemon in California, however, has een identified by that station, and successfully controlled by removing e earth from the trunk and, in several cases, by painting with Boreaux paste.

Citrus blast was found to be prevalent in all citrus groves north of acramento. It is most active in cool, moist weather. Bordeaux ixture was found to be quite effective in its control. A striking ifference was found in the mineral constituents and nitrogen in the aves of citrus affected with mottle leaf and healthy leaves, the former eing high in potash, phosphorus, and nitrogen and low in calcium. here is evidence that excess of soluble sodium salts in the soil lowers e soluble lime; thus the nature of the soil solution is an important ctor in the disease.

The Florida station finds a close connection between melanose and em-end rot. Dripping of water or dew from twigs infected with elanose, or fruiting bodies of the organism taken from dead twigs d inoculated into the fruit, readily produce stem-end rot. There e indications that in the first stage of the growth of the fruit there is susceptibility to melanose spotting, followed by a stage of apparent munity to both melanose and stem-end rot, and a final stage of sceptibility to stem-end rot and immunity to melanose spotting.

It is believed, at the Florida station, that a fungus of the Cercospora pe is responsible for the spotting disease on avocado, which is

sometimes called avocado blotch, frequently associated with Colletotrichum. Both black spot and blotch were effectively controlled by two sprayings with Bordeaux mixture, which is also effective against the scab on this plant. All attempts to control pineapple wilt by soil disinfection were unsuccessful, the only remedy appearing to be in finding resistant strains. A new rot of date fruit, which is becoming serious in Arizona, was found by the station to be caused by an initial attack of an *Alternaria* sp. followed by Aspergillus and Penicillium, the result being a mummifying of the fruit.

In studies on peach yellows, at the Delaware station, bud grafting from a diseased to a healthy tree transmitted the disease, but emulsions prepared from affected trees injected into healthy ones gave negative results. The value of a lime-sulphur dormant spray in controlling leaf curl was demonstrated. The Marietta plum and a peach were found by the Georgia station to be resistant to root knot, and may prove valuable stock for propagating. Sulphur dust was very effective for the control of scab and quite so for brown rot of the peach, at the West Virginia station. Good control of the pear fruit and leaf spot was secured at the New Jersey station by spraying with either Bordeaux mixture, commercial lime-sulphur, or self-boiled lime sulphur. They all caused slight injury except the last one, which was, however, slightly inferior. Perfect control of raspberry anthracnose was obtained at the Iowa station by the use of lime-sulphur solution.

The Connecticut State station has made extensive studies on the white pine blister rust and has determined the channel of infection, its progress and development. The Minnesota station finds that its control lies largely in the eradication of wild currants and gooseberries.

A satisfactory method of controlling bean blight, at the Oklahoma station, was found to be in storing the seed for two years, which absolutely destroys the blight and decreases the germination but slightly. The Michigan station finds indications that bean mosaic may be transferred by aphids and leaf hoppers, and that it is also seed-borne.

Some success has resulted from breeding work with cabbage for resistance to yellows, at the Ohio station. Similar success has been obtained at the Iowa station, where selected strains have given a field stand of 78 per cent, as against 36 per cent from commercial seed. Excellent strains of kraut cabbage that are resistant to yellows have been produced by the Wisconsin station. This station finds that blackleg is due to an internal infection of the seed, which is not controlled by ordinary seed treatment, emphasizing the necessity of careful seed selection.

The causal organism of chili blight has been found by the New exico station, and named *Fusarium annuum.* Its activities are osely related to the soil moisture, it being no longer troublesome nen this falls below 12 per cent, which suggests a method for its ntrol.

The Michigan station finds that the sunflower is a host of cucumber osaic. Attempts to control eggplant blight by spraying have not oved very successful at the Louisiana station. The wilt of this ant was controlled by seed-bed sterilization and crop rotation at e New Jersey station.

At the Iowa station, downy mildew of lettuce was effectively ntrolled by applications of Bordeaux mixture. The disease is und to be prevalent in wild lettuce, and the eradication of this is erefore an important sanitary measure. At the Kentucky station, lure in growing head lettuce in the greenhouse was found to be e to a Fusarium, the only remedy for which seems to be soil rilization.

The Texas station finds pink root of onions to be caused by a ecies of Fusarium and to be carried over in the soil. It is widespread er the United States. The Georgia station reports that pepper osaic is distinct from that of the wild pokeweed, and is not soil-nsmitted. A new Fusarium was found on squash by the Texas tion. Studies at the Delaware station on sweet-potato pox, ich is a serious trouble in the State, show it to be transmitted by ected soil, and can not be corrected by applications of manure and tilizers, its control probably lying in rotation. It also attacks ite potatoes.

Considerable work has been done on tomatoes. The Ohio station been quite successful in developing strains resistant to Fusarium t, Septoria, and fruit rots. The Maryland station has developed ains which are being widely grown and show no signs of losing ir resistant character. It is found, at the Georgia station, that ection occurs most commonly through any of the softer tissues of plant, the fungus not being able to penetrate mature cell walls hey are at all thickened. Studies at the Maryland station show t tomato blight is not seed-borne, but is disseminated mainly by d and water. It lives over winter in the soil in the Septoria ge and spreads quickly in rainy weather. Spraying and early urity were found necessary to control Alternaria early blight at Texas station. Studies on winter blight, at the Pennsylvania ion, indicate that while the initial infection is from diseased seed, common methods of pruning and handling the plants, as well as common insects, as the white fly, are instrumental in spreading disease in the greenhouse. At the Indiana station, tomato

mosaic, which causes serious damage in the State, is found to live over winter in the rootstalk of the ground cherry. A new bacterial disease has been found, causing black, scabby spots on the fruit. The causal organism is carried over in the seed, and successful control was secured by treating these with a 1 to 3,000 solution of mercuric chlorid for 5 minutes.

Three distinct species of Fusarium were found in the wilt of watermelons at the Texas station, two being new ones that will only attack this plant. The causal organism of anthracnose was found to attack other cucurbits. It causes serious damage in wet seasons. Spraying with Bordeaux gives promise of its control. The organism causing stem-end rot was identified as being probably the same as that causing a rot of sweet potatoes.

ENTOMOLOGY.

A study of insecticides at the Oregon station showed that acid preparations were more toxic than neutral or alkaline A dilution of 1 pound of acid lead arsenate to 400 gallons of water was effective for small tent caterpillars and probably others. The commercial lead arsenate was found to be the nearly pure acid salt, the powder form being physically superior to the paste. Tests show that the addition of a spreader increases the efficiency very much, for which purpose calcium caseinate, glue, gelatin, or oil emulsion may be used. Calcium arsenates were found to have a high killing efficiency as a poison spray for chewing insects. Nicotin sulphate was found to be very effective.. At the Washington station the best results with lead arsenate were obtained with a strength of 1 pound to 75 gallons of water. A study of the insecticidal properties of the pine oils and creosotes, at the Maryland station, show the most volatile fractions to be the most active, the residues being practically worthless. The Pennsylavania station, in a comparative study of dusting materials containing definite percentages of nicotin sulphate and the liquid spray, found that the results were strongly in favor of the liquid application.

Bee studies, at the Kansas station, show that if satisfactory methods of wintering are practiced, losses are very much diminished and the production of honey is materially greater, best results being obtained by the use of windbreaks and packed two-story hives. To prevent the introduction of foul brood in bee colonies, the Wisconsin station recommends that hives and frames be scraped and thoroughly washed with hot lye water instead of scorched, as is usually done.

The codling moth was well controlled, at the Connecticut State station, by dusting with sulphur and lead arsenate, and red bugs by adding nicotin to the dust. Soap and strong lime-sulphur sprays were promising in controlling the European plum moth. At the

Delaware station magnesium arsenate has given results equal to those given by lead arsenate in codling-moth control and with little, if any, injury to foliage. The moth was found to be attacking walnuts, in California, by the station, and was controlled by spraying or dusting with one or two applications of lead arsenate. At the Indiana station, no well-defined second brood was found, and it was necessary to spray all summer to catch them all. At the New Mexico station there were found to be four broods in the State, 75 per cent of the eggs being deposited in July and August, and a spraying schedule has been worked out on this basis.

The best method of controlling crickets, as worked out by the South Dakota station, is plowing and harrowing the fields. Burning piles of old hay and straw also destroys large numbers. The use of poisoned bait has been of little benefit directly, although many crickets are killed by eating poisoned grasshoppers. Studies on cutworm control, at the Nebraska station, indicate that this is probably largely a question of rotation and cultivation.

Investigations on the use of poison bait for the control of grasshoppers, at the Montana station, showed that amyl-acetate could replace lemons in the formula, being much cheaper and easier to use. Its use has resulted in the saving of several thousand dollars in one season. It is conservatively estimated that the saving of the hay crop in one locality as a result of a campaign on grasshopper control carried out by the station was over $100,000, and that the saving throughout the State, due to prompt control measures emanating from the station, must have amounted to several million dollars. A study of the habits of this insect showed that they feed most heavily between 10 a. m. and noon and cease feeding almost entirely by 4 p. m.

Life-history studies of the fish moth, at the Oklahoma station, show that a year or more is required for each brood. For its control, as well as for smaller roaches, the Michigan station finds that sodium fluorid gives very good results. The control of the big American roach has been successful with cake or fermented gruel with molasses, poisoned with lead arsenate.

The Maryland station was successful in controlling the boxwood leaf miner by trapping the adults with sticky materials. A chicken mite, new to the locality, was found by the Indiana station. It had been reported previously only from Maryland and Illinois. The chrysanthemum midge and red spider have been controlled, at the Michigan station, with nicotin sulphate and red pepper.

Studies on the control of the root maggot, at the New Hampshire station, by the use of tobacco dust and lime, showed that the degree of fineness of the dust does not affect the repellent action to any extent. The repellent quality of the tobacco is not impaired by

dilution with lime up to 4 parts of the latter to 1 of tobacco dust Two applications were more effective than one. The infestation or the untreated plats was 70 per cent, on the treated plats 18 per cent Cabbage is quite resistant to attacks of the root maggot, but radishes and turnips need protection. Lime was found to be an efficient remedy for controlling bean and cowpea weevils, at the North Carolina station.

The Oregon station has made a detailed study of predacious and parasitic insects, especially enemies of apple aphids and leaf rollers. While climatic conditions do not seem to be very favorable for their action, there is some promise of establishing certain predacious forms that have been introduced from the East.

Almost complete control of the bud moth, in late summer feeding on apples, was obtained at the Pennsylvania station by delayed dormant spraying with arsenicals, followed by the complete schedule of sprays.

The New York Cornell station finds that the hawthorns are native hosts for at least seven serious insect pests of apples. Attempts to control the apple maggot, by the use of sweetened arsenicals, at the New Hampshire station, were not successful. The Colorado station secured good control of the apple leaf roller by spraying with miscible oils before the eggs hatch in the spring. The New Jersey station reports that the use of paradichlorobenzol has been very successful in destroying the peach borer. Two dusting application of nicotin with sulphur and one of sulphur and lime gave 94 per cen control of the terrapin scale on peach trees, while one applicatio gave only 75 per cent control at the Maryland station. At the Ne York State station, the pear sinuate borer was controlled by sprayin with lead arsenate. Experiments have indicated the superiority c miscible oils and nicotin over other spraying mixtures for combatin the pear thrips. Studies of the spinning sawfly of the plum, at th South Dakota station, showed that 50 per cent are destroyed b parasites and ants. Spraying with one-half pound of dry or 1 poun of paste lead arsenate, in 50 gallons of water, when the larvæ ar quite small, gave good control.

In the entomological work at the Florida station, it was found th thrips cause the destruction of a great deal of the bloom of citr trees, and in cases of heavy infestation and light bloom, sprayin increased the amount of fruit about 300 per cent. One spraying wa found to diminish the amount of thrips-scarred fruit about 50 pe cent. The camphor thrips was found to be a native insect, occurrin on a species of wild bay tree. It may be controlled on the campho by spraying or by cutting the trees close to the ground each yea but it is a question if either of these methods is commercially pra ticable. Nematodes have been successfully controlled by applyin

sodium cyanid at the rate of 600 pounds per acre, wetting the soil to a depth of 18 inches and following immediately with an application of ammonium sulphate. The cost is about $200 per acre. Sulphur was found to be of no value as a remedy, and summer fallowing for this purpose is not advisable, as it impoverishes the soil.

The Mississippi station notes the possibility of the hickory bark beetle becoming a serious pest of the pecan. Adults have been found feeding on twigs of the latter.

The cranberry blossom worm was readily controlled, at the New Jersey station, by covering the bogs with water for 24 hours about June 2. The Arkansas station finds the control of the strawberry weevil to lie partly in cultural methods. Dusting also gave good results. Among the varieties Aroma appears to be practically immune.

The striped cucumber beetle was successfully controlled, at the Ohio station, by dusting with a mixture of 20 parts of land plaster with 1 part of lead arsenate, by weight, when the plants first came up, followed by three or four applications about a week apart. At the Massachusetts station, baited flytraps caught a large number of flies of the onion maggot, which was found to be an easier and less expensive method of controlling this pest than spraying.

The Alabama station reports that dusting cotton with calcium arsenate was quite efficient in controlling the boll weevil if properly done. It should begin about one month after blooming and be repeated every five or six days for several applications. The net profits from this practice were found to be about $20 per acre. At the Mississippi station the use of this remedy gave an increase in the crop of 155 to 236 pounds per acre.

Investigations on the potato leaf hopper have been carried on at a number of the stations. At the Michigan station it was controlled with Bordeaux mixed with lead arsenate and nicotin, and the Wisconsin station reports similar success with Bordeaux. At the Pennsylvania station complete control was secured both with Bordeaux and nicotin and by heavy applications of lime, but the latter decreased the yield. At the Iowa station it was found living and breeding on curly dock, indicating that this is an important host plant. All of the nymphal stages were found to be capable of producing symptoms of tip burn, but the older the nymphs, the greater the injury. The adult hopper is not as effective in producing the disease as the nymphal stages. Two sprayings with Bordeaux, 4:4:50, with an addition of 9 ounces of nicotin sulphate to each 50 gallons, gave good protection.

The California station has made extensive studies on the connection of leaf hoppers with sugar-beet blight. The insects leave the beet fields in the fall, going to the foothills, where they winter over, the

spring brood hatching on wild hosts, of which 38 species have been found, and migrate back in the spring, carrying the disease. Some stragglers, however, may remain in the valleys over winter. The migrating dates have been determined in different sections of the State. Beets planted early, in December or January, generally escape infection. A noninfected insect may become infected by a plant before the disease shows on the latter. The insect does not appear to be simply a mechanical carrier, there being evidence that there is an incubation period in the body of the insect. Pulverized clay containing 10 per cent of a commercial preparation of nicotin sulphate at the rate of 100 to 150 pounds per acre will kill the insect if the preparation used is of full strength. The loss is very serious, whole crops being often destroyed, the maximum injury occurring every five or six years. Studies on the sugar-beet root louse, at the Montana station, have demonstrated its effective control by irrigation practices which have been worked out by the station. Growers are adopting it, the saving being estimated at many millions of dollars.

The Alabama station finds the cowpea louse to be the same as the cotton and melon louse and that the locust and spindle tree are also hosts. It changes its color and size on different hosts and has thus been given different names by various observers. A number of host plants of the velvet-bean caterpillar have been found by the Florida station, including kudzu, the horse bean, and a species of carica. Frost kills it out each winter, but it migrates from the South, and it is possible to predict caterpillar years from the occurrence of frost and cold periods in the southern part of the State.

Studies on the aphis which occurs on sunflowers (*A. helianthi*), a the Colorado station, show that it may have a number of plants for a winter host, among them the dogwood, yucca, and milkweed, an it has been described as a distinct species from each of these plants.

The Kentucky station finds that both the northern and souther tobacco worm have at least two broods annually, with possibly late third, but both pass through changes in the field together an can therefore be treated alike. It is recommended that the crop b sprayed each year about the middle of June, making some allowanc for the forwardness of the season, and again on August 1, followe by fall plowing to destroy the hibernating pupæ. The tobacco fle beetle was effectively controlled, at the North Carolina station, b dipping the plants in calcium arsenate at the time of transplantin

The Ohio station reports that with complete weather observation especially in the level prairie regions, the best wheat-planting dat to escape the Hessian fly can be accurately determined. Seven da after the maximum emergence gives the best results, the date, whic varies with conditions, being determined each year. The Sou

Dakota station finds three broods of the wheat-stem maggot, one in June, one in July, and the third in September or October, the first being the most injurious. A number of host plants have been found, including many cereals and wild grasses. Poison bait and trap crops have given fairly good results in its control.

The Mississippi station has made extensive studies on the crawfish. Its eradication with carbon bisulphid has been successful, killing 98 per cent if applied at the right time, and one repetition clearing up a field, but is rather expensive. It costs $7 to $8 an acre to treat by hand, and a strip 30 yards wide is necessary to prevent migrants from outside lands where they are abundant. A young crop of corn or cotton may be entirely destroyed by them in one night if rains come.

FOODS AND NUTRITION.

Much work has been done by a number of the stations on the subject of the vitamins. The Connecticut State station has made important contributions on the distribution of water-soluble vitamins. These studies, with those of other investigators, place the dietary importance of green vegetables in an entirely new light and emphasize their use as supplements to products rich in proteins, fats, and carbohydrates, but in many cases comparatively poor in vitamins. Fruits and vegetables are found to owe their well-recognized usefulness largely to their rich vitamin content. Potatoes were not found to be especially rich in vitamin, and no difference was found in this respect between old and new potatoes or between the peel and inside of the tuber. Tomatoes were found to be rich in both water-soluble and fat-soluble vitamins, as well as the antiscorbutic vitamin, and these showed a potency superior to other vegetables tested. Beets were less potent in this respect than most other vegetables.

Alfalfa, clover, spinach, and carrots were found to be rich in fat-soluble vitamin, which was about as efficacious as that in butterfat. The juice of oranges, lemons, and grapefruit is about as rich as cows' milk in water-soluble vitamin, while pears, apples, and other fruits contain only small quantities of it. Fat-soluble vitamin is either low or absent in fruits. It has been demonstrated that milk is one of the best carriers of this form. The milk of cows on grass was not found to be particularly rich in water-soluble vitamin, being about the same as human milk in this respect. The fat-soluble vitamin in butterfat is quite stable and was found to be effective after heating to 120° C. for 16 hours. In a comparison of grains fed to rats, including wheat, oats, barley, and rye, barley gave the best results. Oats were not eaten readily. Rye produced a good growth at first, but its continued use was followed by a high mortality. Wheat was found to be adequate for producing growth.

Water-soluble vitamin is found to be essential under all conditions, while fat-soluble vitamin is not so continuously necessary. A method has been devised for concentrating the water-soluble vitamin of yeast to about 6 per cent of the extract. At the Iowa station, xerophthalmia, a disease caused only by deficiency in fat-soluble vitamin, has been produced in rabbits under conditions that suggest that herbivora require more of this element than omnivora, as swine or rats, swine showing considerable tolerance for such a deficiency.

Experiments at the Wisconsin station show that the concentration of the antiscorbutic vitamin in milk is dependent upon the diet, summer-pasture milk being much richer in this element than dry-feed milk, involving the use of corn silage or mangels. Extensive studies have shown that fat-soluble vitamins are constantly associated with the yellow pigments of plants, but in animal tissues the association is not so marked.

The Arkansas station finds the Georgia velvet bean to be very rich in fat-soluble vitamin, but the seed is found to be low in salts and the hulls to have no supplementary value. The leaf is the most nutritious part of the plant, in that it furnishes the necessary salts and is fairly rich in water-soluble vitamin.

Wisconsin station experiments on nutrients from single plant sources showed that a ration made from the oat plant, both grain and straw, was inadequate for the nutrition of breeding cows, the offspring being born prematurely and either very weak or dead. The addition of fat-soluble vitamin or of casein did not improve the ration for reproduction. When calcium salts only were added, however, a marked improvement was noted. The data secured indicate that where all other nutritive factors are satisfied, the ration of a dry breeding cow should contain at least 0.45 per cent of calcium oxid. Marsh and timothy hay, where they contained as much as 1 per cent of calcium oxid, were found to be very efficient roughages for reproducing cows. Alfalfa hay was found to be particularly efficient in maintaining a positive nitrogen balance in dairy cows.

At the North Dakota station, calves and yearlings, fed on high and low protein rations of equal net energy, showed no distinct differences attributable to the rations. Similar studies with calves at the Virginia station indicated that the protein was less efficiently digested in a low-protein diet, showing that it is more economical to have a liberal amount of protein in the ration. Studies on the protein and energy requirements for milk production showed that 1.87 pounds of digestible protein was required to produce 1 pound of protein in milk, or 0.053 pound of protein to produce 1 pound of milk. The amount of energy required in the food to produce one therm in the milk was 1.05 therm, or 0.315 to produce 1 pound of

milk. The experiments indicate that when a cow begins her lactation period with a lack of digestible protein and excess of energy, her digestion coefficients fall, she loses flesh rapidly, and her milk flow continues to decrease, at first rapidly and later more slowly.

A study of the protein compounds of corn, at the Illinois station, showed the deficiency of corn for the growth of young animals to be due to two amino acids and too low protein concentration. Vegetable proteins proved to be as valuable for maintenance as milk proteins, but not for growth. A study of the best time to cut corn to get the greatest amount of nutrients showed a gradual increase up to the ordinary time of cutting, at which time there is more dry matter, fat, and carbohydrates than before or after, there being about 10 per cent less a week earlier or later. It was found that corn stover silage would maintain beef cattle at a cost of 7 cents per head per day when fed with 1 pound of corn, but was suitable for maintenance only, not for fattening or milk production.

The Ohio station finds that the potential acidity and alkalinity of the supplement in a ration affects the alkali reserve of the blood. Calcium carbonate increases this, while the bicarbonate, a potential acid, decreases it. A study of the comparative value of calcium compounds for swine indicated that the relative solubility was of little importance, the principal factors being mechanical condition and palatability. An animal can take more calcium phosphate than carbonate. Steamed bone with 10 per cent tankage was a good mineral supplement for swine and steamed bone with one-fourth salt for cattle. The Iowa station finds that swine are not only tolerant to acid rations, but rations made strongly alkaline with sodium hydrate and carbonate were quite efficiently handled.

The Pennsylvania Institute of Animal Nutrition has deduced a simple formula by which the heat production of a resting animal may be computed from the live weight, food consumed, and carbon dioxid produced, and a simple method has been formulated by which the amount of animal heat available as the motive power for ventilation may be approximately computed.

ANIMAL HUSBANDRY.

A study of age as a factor in animal breeding carried on at the Missouri station with cattle indicated that if conditions were good pregnancy seemed to have no bad effect on the growth of heifers bred as young as possible, but it is inhibited somewhat by lactation. The offspring of young heifers, although somewhat smaller at birth, are just as vigorous and capable of maximum development as the offspring of mature cows, but growth is a little slower, and with hogs it required about two weeks longer for the offspring of very young mothers to reach 250 pounds.

Experiments have been completed at the Missouri station on the growth that may be expected of normal beef animals when fed all they will eat, a ration for growth only, and one representing poor farm conditions, from birth up to 4 years of age. The first group weighed 2,000 pounds at this age, the second 1,000 pounds, and the third 1,200 pounds. No difference was noted in the height, but in length there was a decrease of 10 to 12 per cent and in the girth at the chest of 20 to 25 per cent with the lower rations as compared with the higher. The effect of plane of nutrition on subsequent development showed that a starved animal put on a full ration made a more rapid gain at a cheaper rate than a full-fed one, but never caught up in total weight.

Very favorable results have been obtained at the Nebraska station in the raising of dairy steers for beef. The percentage of high-priced cuts did not vary essentially and the quality of the meat was equal to that of medium fat steers of the beef breeds.

The Texas station reports that $1\frac{2}{3}$ tons of silage are equivalent to 1 ton of cottonseed hulls for fattening steers. Peanut meal proved of equal value to cottonseed meal and produced no bad effect on the carcass, but apparently was not as palatable. Tests of the value of silage for feeding breeding heifers at the Wyoming station showed a reduction in cost and an increase in rate of gain by its use. In a comparison of corn and sunflower silage fed to beef heifers at the Oregon station palatability was an important factor in the amount eaten, and the gain for the first year's experiment was larger for the corn silage. The same held true with dairy heifers. In feeding experiments at the Oklahoma station sunflowers have proved so satisfactory that they are now being grown quite extensively for silage. Successful results were obtained at the South Dakota station with silage made from millet, it being eagerly eaten by steers and fair gains made.

In steer-feeding tests at the Wyoming station, decreasing the amount of alfalfa hay increased the cost of gain. Pea straw proved very satisfactory at the Washington station for both cattle and sheep. The digestive coefficient of both carbohydrates and proteins of this material is very high. At the Pennsylvania station the use of molasses as a source of carbohydrate for fattening cattle proved economical and beneficial. Cattle receiving 4.6 pounds of molasses in place of an equal amount of corn made 0.25 pound heavier daily gain and outsold the other cattle 50 cents per 100 pounds on the market.

At the Utah station, a liberal amount of grain supplement (corn and mill run) fed with alfalfa hay to steers was found to be economical and profitable. One lot on alfalfa hay alone gained 171 pounds in 90 days; another lot, with the addition of 12 pounds of grain,

gained 235 pounds. Experiments as to the extent to which cottonseed meal may be fed to live stock, at the North Carolina station, showed that in fattening cattle, up to 10½ pounds per head daily could be fed without bad effects, if the animals got a succulent roughage like silage, but on dry feed there was some injury. With sheep, feeding up to two-thirds pound a day caused no difficulty, except that the ewes fed this amount lambed earlier than normal, although the lambs were healthy.

The North Dakota station found it profitable to finish up grazing steers on corn before marketing, the average returns being $60 per acre for the corn. The heaviest gains by steers on the range were made in the early part of the season, with corresponding less gains in the summer and fall. Five acres of pasture were found necessary to carry a two-year-old steer. At the New Mexico station, cows that were properly maintained during the winter, by a little feed in addition to that furnished by the range, produced calves that averaged at birth 11 pounds more per head and 73 pounds more at weaning time than calves from cows kept wholly on range. All of the fed cows produced calves the second year, while only 1 in 5 of the range cows produced a calf.

Attempts at the Oklahoma station to secure winter and fall lambing are giving some results, the early lambing character seeming to be imparted by Dorset and Rambouillet crosses. Sheep fed in the open, at the Missouri station, required 6.4 bushels more corn per 100 pounds of gain than a lot fed the same ration in the barn.

In a comparison of sunflower with corn silage, at the Oregon station, while the former did not seem to be as readily eaten at first, later it was eaten with great relish and the gains reported were in favor of the sunflower silage, both in cost and amount of growth. Sunflower silage for lambing ewes, at the Nevada station, gave a heavy increase in the milk supply and better nourished lambs. This is important, because sunflowers will grow where corn is a failure. At the Montana station, sunflower silage was not found equal in feeding value to alfalfa hay, for wintering breeding ewes, although the ewes fed upon it came through the winter in fairly good condition and produced normal lambs. The Missouri station finds that clover hay alone is sufficient to maintain pregnant ewes up to lambing time. From one-fourth to one-half ounce of salt daily for pregnant ewes was found to give good results, at the Iowa station.

At the Missouri station, lambs from a purebred ram brought $7.35 per 100 pounds, while those sired by a scrub ram, at the same age and on the same feed, sold for only $4.50 per 100 pounds. The first lot weighed more at three months than the second lot at four months.

An experiment at the Texas station, comparing gains made by crossbred and purebred lambs, led to the conclusion that when lambs are raised under range conditions, in western Texas, there is no special advantage in crossing mutton rams on fine-wool ewes. The fine-wooled sheep are more hardy, better rustlers, and withstand extreme range of temperature and drought better.

The grain sorghums are extensively grown and are the safest crop in western Texas. A test of their feeding value for lambs showed them to have 93 per cent of the value of corn, whereas the market price averaged 20 per cent higher for corn than for milo. The test showed conclusively that corn shipped into that section could not compete successfully with the grain sorghums for fattening lambs. A profit of $1.25 per head was realized, at the Oklahoma station, on lambs fed on alfalfa silage and shelled kafir. In a comparison of oats and barley with corn for fattening lambs, at the Iowa station, with a complete substitution, the oats had a value as compared with the corn of 77.5 per cent and the barley 91.95 per cent. At the Kansas station, self-feeders were not successful with sheep, as they do not choose a balanced ration. The cost of 100 pounds of gain when hand fed was $13.27 and on the self-feeder $15.82.

Wool studies at the Wyoming station showed the breaking strength of both scoured and unscoured wool decreased and the elasticity increased, with increase of moisture. Wool fibers, exposed to the weather, lost about 30 per cent of their tensile strength by the end of one month and at the end of the second month had deteriorated too much for further testing. Studies on the effect of alkali showed that sulphate of magnesia and sulphate and carbonate of soda did not materially increase the injury of samples of wool exposed to the weather.

Investigations in swine husbandry have been quite extensive. Studies on the effect of feeding cottonseed meal on breeding showed that if the animal is in good condition there were no apparent effects on the spermatozoa until symptoms of poisoning begin to show, when they deteriorate. At the Missouri station, fattening hogs gained 32.6 per cent faster on a ration of corn and tankage and 38.5 per cent on a ration of corn and soy beans than on corn alone. A faster gain of 7.4 per cent was made when self-fed than when hand-fed on the same ration. The saving of grain resulting from the use of pasture crops was from 20 to 50 per cent. Of the forage crops tried, clover gave the highest returns, being 567.7 pounds of pork per acre.

The Iowa station finds that oats are not profitable for fattening hogs, having only from 40 to 65 per cent of the value of corn, but for growing pigs the relative value was 93 per cent that of corn.

Some striking results were obtained in feeding orphan pigs, on the ffects of adding feeds carrying vitamins in abundance. Five lots f pigs were fed for 90 days, by the "free-choice" method, on a mixure of shelled corn, meat meal tankage and salt, with a quart of hole milk daily per pig for the first 60 days. The check lot received nly this basal ration and were fairly healthy. One lot received, in ddition, the juice of one orange per pig per day, mixed with the ilk, and gained 24 pounds per pig, or 44 per cent over the check lot, ue to the orange juice. Another lot, receiving one egg daily per ig, gained 22.5 pounds or 41 per cent more than the check lot, and a t receiving 5 ounces of tomato juice gained 25 pounds, or 45 per ent over the check lot and were the smoothest finished.

Studies on the effect of the amount of fiber in the ration for fatening hogs, at the Indiana station, showed that with 5 per cent there as some depreciation in the gains, which became more marked as e fiber increased, 10 per cent showing a decided hindrance to rapid nd economic gains. Corn and tankage containing about 2 per cent f fiber gave the most satisfactory gains. Some commercial feeds ere found to have as high as 20 per cent of fiber.

Feeding blackstrap molasses to hogs, at the Mississippi station, owed about 1.8 pounds to be equal to a pound of corn. At the regon station, cane molasses was fed in comparison with barley, the sults showing that it could be fed up to 45 per cent of the ration ithout injury, and was equal to barley, pound for pound.

Winter wheat, sown in the spring, proved to be good pasture for ogs. A comparison of forage crops for swine at the North Dakota ation demonstrated the superiority of alfalfa for this purpose and so that grazing is a necessary practice for economic pork production. t the Oklahoma station, sweet clover gave a better pasture for hogs an alfalfa, very shallow planting giving the best results. Dwarf ssex rape produced the most economical gains and a greater amount pork per acre than rape with oats or with oats and peas. At the ississippi station, 5¼ acres of corn and soy beans grown together rried 75 hogs for 31 days, with a daily gain of 1.12 pounds per hog, d produced 495.7 pounds of pork per acre.

In a comparison of self-feeding and hand-feeding, at the Wyoming ation, the self-fed group made faster though less economical gains, e indications being that self-feeding is not to be recommended for ung breeding stock.

A comparison of tankage and fish meal, at the South Carolina ation, proved the latter to be a little more economical and to give od gains. Pound for pound it was superior to tankage.

Some interesting results were obtained at the Kansas station on value of alfalfa as a supplement to corn and tankage and kafir d tankage. The corn and alfalfa ration did not give as good

results as alfalfa and kafir, due evidently to a deficiency of protein in the corn. White kafir was found to be deficient in fat-soluble vitamin. The common hog ration in the State is alfalfa, corn, and tankage, which seems to account for the poor results often obtained. Kafir and tankage, supplemented with alfalfa meal, is much more nearly adequate than corn and tankage. Excellent results were obtained at the New Mexico station in feeding pinto, tornillo, and mesquite beans, both to sheep and hogs.

In experiments in feeding barley to hogs, at the Oklahoma station, ground barley gave better results than the whole grain. A test of the best method of feeding barley to fattening hogs at the Indiana station showed good results from mixing ground corn and barley in equal parts by weight and properly supplementing with tankage. If fed ground barley and tankage separately, in self-feeders, an excess of tankage was consumed. The Illinois station finds that a supplementary feeding of mineral matter is unnecessary in a well-balanced ration, but if this consists mostly of corn it is necessary.

A number of investigations have been carried on by the southern stations on the subject of soft pork. At the Oklahoma station it was found that cottonseed meal will harden pork better than corn, and that barley may also be used for this. The melting point of fat of hogs fed cottonseed meal was about 1.5° higher than that of other lots. Studies on rabbits showed that in starvation the liquid and softer fats of the body were used up before the harder fats, which suggests a possibility of thus getting rid of the soft fat of peanut-fed hogs before finishing on hardening rations. At the Kansas station, studies on the effect of feed on the composition of the body fat showed that none of the short-chained fatty acids are deposited in the body fat, while the unsaturated fatty acids are so deposited. The body fat produced on a high-protein diet differs from that produced on a low-protein one.

The Texas station finds that while large amounts of rice bran in the feed will produce a pork classed as medium soft, which, however, is white and will not drip, it may be fed to the extent of 50 to 60 per cent with corn chops and tankage and not produce a carcass that will be classed as soft. It does not appear to be as bad in this respect as peanuts. Pigs receiving a ration of 90 per cent rice bran with 10 per cent tankage, as compared with a lot fed with the self-feeder, made smaller daily gains, but at a less cost per 100 pounds of gain.

The Florida station reports a considerable variation in the melting points of the fat from different hogs on the same feed. From the standpoint of the melting point, anything below 33° C. is rated by the packers as soft and oily, from 33° to 38° C. as medium hard, and over 38° C. as firm. A method has been devised of securing samples

of the fat from the live animal, without injury, which promises important results in studying the effect of feeds. The Georgia station finds that ordinarily the outer layer of back fat is softer than the inner layer, but that this appears to be reversed by heavy peanut feeding.

At the Mississippi station, of hogs grazed on peanuts alone and then finished on corn and tankage in the self-feeder for 4, 8, and 12 weeks, the 12-weeks lot barely got above the soft grade.

As the result of extensive poultry investigations, the California station reports that with 1,000 birds to the acre, three times the profit is obtained than the same acre would yield in alfalfa. Studies at the North Carolina station, on the length of time required for food to pass the digestive canal, showed that this varies largely with the age, activity, and other factors. In nonlaying hens it required about 8 hours and in laying hens a little over 3 hours. With sitting hens the time required was about 14 hours and with young growing chicks about 4 hours.

The New York Cornell station finds it possible, with considerable accuracy, to judge the value of hens for laying by body characteristics, thus enabling the elimination of unprofitable birds while they are young, saving the expense of trap nesting and of keeping undesirable birds until their value is learned, and avoiding the danger of using eggs for hatching from low-producing birds. Continued inbreeding, at the Wisconsin station, has reduced the hatchability of eggs to zero in 5 or 6 years.

At the Massachusetts station, successful results have been obtained in combining a nonbroody and a high egg-laying strain. The results obtained at the Maryland station in culling methods have received wide application.

In investigations on the deficiencies of feed fed to hens as affecting the vitality of chicks, at the Kansas station, it was found that a low-protein diet gave a small number of eggs with a loss in weight. A low fat-soluble vitamin ration gave a fairly good egg production, but the hatchability was very poor and the mortality very high. With a low water-soluble vitamin diet good egg production and hatchability were secured, with chicks normal in size and vigor, but with a loss in weight and a high mortality. It was found possible to vary the vitamin content of the egg by varying this element in the food, especially the fat-soluble vitamin. There was evidently something in green alfalfa and milk that was highly beneficial. It was also found that with chickens fed a ration deficient in fat-soluble vitamin the eyes were affected first, which is believed to account for the prevalence of roup, as birds fed with a ration containing suffi-

cient of this element could not be infected with the disease. At the Minnesota station, a vitamin-free diet of polished rice fed to cockerels caused atrophy of the testes, which did not occur, however, if a small amount of green alfalfa was fed with the rice.

Feeding experiments at the New Jersey station showed conclusively the importance of finishing pullets by heavy feeding of grain in the late fall and early winter, in order that they may come into production in a heavy, natural, well-fleshed condition, thus being able to carry through later in the following summer and to stand up under the strain of heavy and continuous egg production. In an experiment at the Kansas station on feeding single grains to chicks, all died within 5 weeks, corn alone giving the earliest mortality and kafir showing the most gains.

At the Nebraska station a ration of wheat, casein, butterfat, and ash, fed to chicks, did not result in normal growth, which was, however, secured by the addition of 5 per cent of wheat greens. Leg weakness in chicks was found to be due to a lack of suitable roughage in the ration, at the Wisconsin station. With concentrated rations alone this was serious, but 10 per cent of roughage was sufficient to grow normal chicks, and paper was found to answer this purpose. Exercise, green feed, or even orange juice did not prevent the occurrence of leg weakness if the bird was overfed a concentrated ration.

At the New Mexico station, hens fed on alfalfa meal returned 5 per cent of the nutrients fed, in the eggs, but with meat scrap, alfalfa and bran only 28 per cent was returned. At the Oklahoma station a ration containing from 20 to 25 per cent of beef scrap gave the best results. Meat scrap, added to a basal ration, with Plymouth Rock pullets, at the Indiana station, increased the average egg production from 50 eggs per bird per year to 100 eggs, and decreased the cost per dozen eggs 20 cents. The Iowa station found it profitable to feed from 15 to 25 per cent, by weight, of tankage in the mash, which in the summer months, with free range, can be reduced to 10 per cent.

At the Kentucky station, it was found that laying hens, whose supply of lime was limited to that in the food, suffer a general depletion of magnesia, phosphorus, and lime from the bones and carcass with continued egg laying. The addition of limestone or oyster shells to the ration increased the production of eggs nearly 70 per cent.

The Utah station has three hens that have gone without molting for two years and have laid over 200 eggs apiece per year, and attempts are being made to establish this character by breeding.

The Maryland station has made a study on the effect of age on the hatchability of eggs and finds that this begins to decline after seven days. Chicks hatched from eggs kept longer than this are less vigorous. It is found, at the West Virginia station, that the vigor

he embryo, during incubation, can be measured by the carbon dioxid given off. More than half of this is given off during the last quarter of the incubation period, and during that time ventilation should not be restricted.

The fertility and hatchability of eggs in lighted houses was found at the Utah station to be higher than of those from unlighted. Early morning lighting only seems to be most profitable. Artificial illumination of henhouses was originated at the California station. Observation has shown that it gives a change in season of production, but does not increase the yearly output, except with poor layers. The best results were obtained in lighting from October 30 to March , from 4.30 a. m. to daylight. The New Jersey station, on the other hand, finds that lighting for an evening lunch period, between and 9 p. m. gave as good results as when morning or evening lights were used.

DAIRY HUSBANDRY.

At the Maine station, the effect of every Guernsey bull, where records of two or more of his progeny were available, has been worked out, giving a comprehensive and scientific measure of the true breeding worth and value of the various blood lines of this breed, which is one of the most practical results of the station's work for the farmer, dairyman, and breeder.

In a comparison of early and late fall calving, at the Mississippi station, late calving, October 15 to December 31, gave 16 to 17 per cent more milk and fat. Fall calving gave a larger yield of milk and fat than spring calving.

At the Iowa station, the substitution of cottonseed meal for corn caused a temporary increase of 12 per cent in the fat content of the milk. Soy beans proved to be equal to linseed meal, pound for pound, for milk production. Dairy cows were found to have a greater maintenance requirement when in high than when in low condition. The water requirements varied little on account of conditions, but low condition was accompanied by an abundant salt consumption.

A study of the soiling system under Nebraska conditions, by the station, showed that soiling crops correlate well with specialized dairying, in the distribution of labor throughout the day, and that cows will maintain a more constant yield throughout the summer on good ration of soiling crops than on any other feeds, thus decreasing the necessity for a heavy grain ration. The labor required, however, somewhat greater. Dairy calves on the self-feeder consumed a much greater amount of grain than those fed by hand and made a more rapid growth, with a material saving of labor and no ill effects. The Indiana station devised a successful milk substitute for young calves, consisting of a mixture of 12 parts of beef blood, with one part each of corn meal and oil meal.

An analysis of milk records, at the Maine station, shows that the parts of the conformation having a distinctly significant relation to milk production are the milk veins, size and condition of the udder, shape and size of barrel, and the general appearance of the cow; but a seven-day test is superior to conformation as a guide to milk production. Extensive studies of herd records showed that the highest production was in February and March, the lowest being from July to September.

At the Missouri station, dairy cows showed a decided increase in fat in the milk when the rations were diminished, falling off somewhat after a few days, but when returned to full feed the percentage went down rapidly and remained below normal. The amount of milk varied almost directly with the amount of feed.

It was found at the Texas station that with cows fed on cottonseed meal and silage, each pound of butterfat produced cost the station 48 cents. At the Minnesota station, the vitamins in the diet were found to bear a direct relation to the vitamin content of the milk. Spring milk is superior to winter milk in vitamins. With a deficiency of these in the diet they decline very gradually in the milk, but increase rapidly with an improved ration. The vitamin content of butter was found to undergo a seasonal change, as with milk. The Pennsylvania station finds sunflower silage to have only about three-fourths the value of corn silage for milk production, but 20 tons of the former were secured, compared with 12 tons of the latter, per acre. At the Washington station sunflower silage proved to be 92 per cent as efficient as corn silage for dairy cows and to have about 75 per cent of the feeding value of good alfalfa hay.

A comparative test, at the Montana station, of sunflower silage and alfalfa hay indicated that 1 pound of the latter was equivalent to 2.9 pounds of the silage, the milk and butterfat percentage of both being about equal. Results with this material at the Michigan station showed that the sunflower silage alone was not as satisfactory as corn, but a mixture of the two was better than either one.

In an experiment at the Wisconsin station in feeding hydrolyzed sawdust to dairy cattle, 1 pound of treated white-pine sawdust substituted for 1 pound of barley, when fed not to exceed 25 per cent of the ration, was eaten readily and the flow of milk was maintained. Sawdusts containing a large amount of resin are not suited for feeding purposes.

The feeding of coconut, peanut, and soy-bean oils to milk cows, at the Massachusetts station, caused a marked depression in the soluble acids of the butterfat. Coconut oil caused an increase of 1 per cent in the fat. When coconut meal was fed to the extent of 4 pounds per day at the California station it was found to impart a taste to the milk.

The Illinois station has demonstrated that the greatest source of contamination is the milk pail and other containers. The New York State station finds that the carbon-dioxid content of milk is a reliable test as to whether it has been pasteurized. Under the conditions in which normal unheated milk is handled, from milking to delivery to the consumer, the volume per cent of carbon dioxid seldom drops below 3.5, while heating reduces this to 2.5 per cent or less. Normal milk contains about 15 per cent of carbon dioxid, but in diseased conditions it runs much higher. As a rule about one-third is free, the rest being in combination. At the Indiana station, bitterness in evaporated milk was found to be caused by *Bacillus panis*, which has a thermal death point of 250° F. for 10 minutes.

In the use of milking machines, at the New York State station, the chief difficulty was found to be due to the growth of bacteria in the tubes and pails between milkings.

Studies on the cause of metallic flavors of butter, at the Michigan station, showed that they may be caused by certain bacteria of the *subtilis* group. Certain metals, as arsenic, calcium, zinc, and iron, may cause this flavor, but it is transient, while that caused by bacteria continually increases.

At the California station, preserving butter in 30 per cent brine gave good results, keeping it well for five weeks in summer. The Indiana station finds sandiness in ice cream to be due to the precipitation of milk sugar. From 10 to 12 per cent of milk solids in the fat seems to be the upper limit which can be used without producing this condition.

VETERINARY MEDICINE.

Two distinct strains of *B. botulinus* have been isolated at the Illinois station that will not protect against each other. An antitoxin for this bacillus, which is the most common cause of forage poisoning in horses and of limberneck in fowls, has been perfected at the California station, that, while not especially curative, has a distinctly prophylactic effect.

In contagious-abortion studies, at the Connecticut Storrs station, heifers fed with virulent cultures remained negative, but were easily inoculated through the vagina and urethra. It has been demonstrated that the disease is not transmitted from dam to calf. Disinfection of the sheath of the bull, before and after service, is giving excellent results in its control. In similar experiments at the Missouri station of seven heifers from a nonreacting herd, bred to a negative-reacting bull, two were fed cultures of the bacillus and aborted, the bacilli being recovered from the fetus. Two others received injections of the bacilli under the skin and developed a positive reaction, but carried their calves all right, except that they

were seven or eight days premature; the bacilli were recovered fron the placenta and the milk was positive. Two others, in which th bacilli were injected into the vagina, developed a positive reaction calved prematurely, and the bacilli were found in the udder. Tw others, with the bacilli injected into the teats, also calved prematurely Apparently irrespective of the manner in which the germs get int the body, they get into the uterus and milk. Sows' milk will reac before the blood does.

At the Michigan station, *B. abortus* could not be found in the deepe layers of the mucous membrane of the nongravid uterus of animal recently injected with the disease. The Minnesota station finds tha blood tests are of little value in indicating whether an animal ha aborted or will abort, but they do indicate the amount of her infection.

The Kentucky station finds that old cultures of the bacillus o equine abortion, isolated in 1912, retained a considerable degre of virulence. Immunization of mares injected intravenously wit large numbers (20 billion) of the live organisms was not successful such an infection being, however, probably heavier than would b encountered under field conditions. Jennets were found to absor the germ from the intestinal tract into the blood stream when fed liv organisms, as shown by the increase of agglutinins in the blood serum The use of vaccine as a preventative was quite extensively carrie out with encouraging results. Treating aborting cows with bacteria vaccine made from strains of the bacillus from aborting animals followed with subcutaneous injections of a live culture of the sam organism, gave encouraging results as a means of combating th disease.

Tests of commercial bacterins for the control of contagious abortio at the Wyoming station, showed them to be of no value. The Illino station has demonstrated that the microorganism of contagiou abortion of cattle is a factor in this disease in swine. In tests carri on for three years, at the Arkansas station, transmission of bovin infectious abortion to swine by feeding milk from infected cows h not been successful. The Illinois station finds swine abortion to b an infection of the individual fetus rather than of all the embryo some pigs in the litter being positive to *B. abortus* (Bang), others no In the Chicago market, only 0.56 per cent gave a positive bovin abortion reaction.

In an extensive study of a hemorrhagic disease occurring in catt at the Nevada station, the causal organism was not found, but a seru was produced that, with treatment, has reduced the mortality fro 95 to 44 per cent. Attempts to identify it with hemorrhagic septic mia were not positive, but the indications are that it is infectious.

Studies on tuberculosis, at the California station, showed that it was not possible to produce infection by tubercular-infected dust. Some success has attended attempts to immunize against *B. necrophorus* infection in rabbits, at the Wyoming station, by the use of a vaccine from the serum of the blood of an infected rabbit.

Studies on the transmission of swamp fever in horses, at the Wyoming station, indicate that the nasal secretions, which are often abundant in affected animals, may be a source of infection. It is also transmitted by the bites of at least two species of flies. The blood of one horse was found to be highly virulent 4½ years after it became infected. No satisfactory diagnostic character has as yet been found, and it seems to be impossible to detect certain chronic cases by ordinary means. The Texas station also reports indications that this disease is transmitted largely by the stable fly. At the North Dakota station, all attempts to produce the disease by means of Gastrophilus extracts have been unsuccessful. Studies on this disease, at the Nevada station, showed that severe infections of parasites may give symptoms very closely resembling it. It appears to be induced by a filterable virus and can be produced by inoculation. No specific diagnostic method has been found and no successful treatment discovered. It also reports the probability of its transmission by biting flies. It is confined wholly to the horse family.

Studies on anthrax, at the Louisiana station, have shown an organism to be very commonly present that is very similar to the anthrax bacillus that may lead to a wrong diagnosis. The organisms are motile, while the anthrax organisms are not, and they are nonpathogenic to guinea pigs.

At the Maryland station, it was found that pigs from immune mothers, inoculated with hog cholera, in all cases showed no symptoms until they were weaned, when they all came down with the disease. Studies on the infectiousness of the blood, urine, and feces from hog-cholera infected animals, at the Indiana station, showed that when these materials were fed to healthy animals in no case did the urine or feces cause infection, but feeding the blood produced the disease. It is not believed that the disease is transmitted by flies, but may be by dust. At the Kentucky station it was found that feeding arsenious oxid to hogs, following the injection of cholera virus, prevents infection. Shaking the virus followed by storage at 4° C. decreased its virulence. Virus containing 1 per cent phenol maintained its full virulence for 96 days at 4° C. The Louisiana station has made a study of the mixed infections that frequently follow inoculation of swine for hog cholera. This was found to be widespread and evidently due to reduced vitality caused by the inoculation. It develops rapidly and the hogs die in large numbers. The only means of control seems to be proper sanitation.

In a study of hairless pigs, at the North Dakota station, it was found that in many cases thyroid symptoms were entirely lacking. Hairless litters were found to be about 10 per cent smaller than normal ones, and hairlessness appeared to be most common in litters of gilts. In two lots of sows, fed the same feed, one lot being given exercise and the other lot closely confined, the latter produced hairless litters, the same results being obtained when the lots were exchanged. The condition is not inheritable and seems to be worse some seasons than others. The Washington station secured perfect control of the trouble by the use of iodin.

At the Wyoming station, studies on the muscle parasites of sheep indicated that an intermediate host is not necessary, that there is an apparently infective intestinal stage, and that infection results from eating food contaminated with infected feces. While complete control would seem to be impossible, infection can be reduced to a minimum by avoiding restricted grazing and by scattering the flocks in the morning as they start out from the bedding ground. Moist or wet pastures favor infection, and it is therefore advisable to graze the sheep on drier ranges, especially in the forenoon. Heavy infections of the lungworms of sheep were obtained, at the Oklahoma station, when the eggs were fed. They cause atrophy of the lungs and pneumonia often results. Larval worms have been kept alive in soil and on vegetation, in a dried or partially dried condition, for 14 months.

In studies of the fringed and broad tapeworms of sheep, at the Wyoming station, it was found that natural infection is, as a rule, associated with feeding in damp localities. The Connecticut Storrs station finds that the larvæ of stomach worms of sheep will live over in pastures in the State and that the eggs hatch outside of the body of the sheep. There seems to be some curative value to calcium sulphate and tobacco. At the Texas station it is believed that swell head of sheep and goats may be due to eating blossoms of the Sachrista. Affected flocks, removed from locations where this plant occurs, showed no more symptoms. Treatment with 5 grains of calomel, followed in 12 hours with 6 ounces of castor oil, gave good results.

Results of studies at the Maine station show that the alexins o complement bodies of the blood necessary to complete the chain for th binding of the foreign protein that takes places in disease resistance are lower in the fowl than in most animals. The Nebraska station i led to to the conclusion that fowl cholera is a form of hemorrhagi septicemia. The use of bacterins and vaccines has not proved ver efficient for its control.

The Oklahoma station finds that the roundworm of poultr (*Hymenolepis carioca*) may be transmitted by the stable fly, Sto moxys. When roundworm eggs are fed to chicks they do no develop and are passed out, but when then eaten by chickens the

develop. For their control, chenopodium acted harmfully on the chicks, but a mixture of chloroform, male fern, and tobacco was from 50 to 70 per cent effective. Santonin gave a 50 per cent control of ascarids and 25 per cent of tapeworms. Studies on the nematode roundworm at the Kansas station showed that the eggs as passed in the feces are very resistant, developing after 7 days' exposure to summer sun and 15 hours of continuous freezing at a temperature of 11° F. below zero. Studies of the chicken nematode Heterakis, at the Minnesota station, showed that no intermediate host is required and there is no evidence that the larval forms undergo migrations comparable to Ascaris. Tests with various chemicals and heat, for control, have not been very successful. Viable eggs of the nematode were secured from fowls that had been in cold storage over 9 months.

Very successful results have been secured, at the Kansas station, in the production of pure-culture vaccines for the prevention of roup and fowl typhoid. In treating a large number of birds, in infected flocks, less than 1 per cent acquired the disease. The use of an autogenous vaccine, at the New Jersey station, made directly from the virus from scabs of birds infected with chicken pox, gave very positive results in control of the disease.

The Maryland station reports that the remedy for blackleg and gout of poultry rests on proper feeding. Hens were found to show symptoms of gapes 11 days after being fed infected earthworms.

In a study of blackhead of turkeys, at the Rhode Island station, it was found that flagellates occur in domestic poultry as well as in many wild species, corresponding to the occurrence of *B. coli* in the human species, and it is believed that when these organisms become abnormally numerous or active they cause blackhead, the relation being similar to that between *B. coli* and colitis in man.

Experiments on the use of nitrobenzol as a fumigant for the control of external parasites of poultry and other animals, at the Michigan station, indicate that it can not be used with safety on account of its toxic action, although it may be used, with caution, for collecting parasites, by fumigating at low temperatures for short periods, but is dangerous to use under any condition.

The Nevada station has made some investigations on the biting flies of cattle, and finds that *Tabanus phænops* must have a liquid or semiliquid medium for development, and the larvæ will not mature in well-drained land. It may be controlled by this means. It is believed that this species may carry anthrax.

AGROTECHNY.

Studies by the Louisiana station on the clarification of cane juice show that this rests mainly on adsorption and that it may be accomplished without the use of chemicals. By the use of certain adsorb-

ents, followed by filtration, the same quantity of first sugar of greatly superior quality can be made, the first molasses being very light in color, the recovery of high-grade sugar made directly from cane is increased, and a final molasses with an enhanced value is produced.

The station has also studied the cause of the darkening of cane juice. If the juice was not left alkaline after clarification there was no discoloration as a rule, except in the presence of tannin, which gives a dark-colored sirup, whether iron is present or not, although the presence of the latter gives a darker color.

Excellent results were obtained by the use of decolorizing carbons made from sawdust impregnated with magnesium or ammonium chlorid. The practicability of making a clear, white juice was demonstrated, from which sugar can be crystallized in a condition that needs no further refining, by filtering the raw juice through kieselguhr and treating with 1 per cent of its weight of a decolorizing material. A study of the cause of the deterioration of stored sugar, mainly by inversion, showed the chief cause of this to be molds, the remedy being proper drying under sanitary conditions.

AGRICULTURAL ENGINEERING.

The Utah station finds that four 6-inch irrigations on sugar beets gave a yield of 15.23 tons per acre, and four of 3 inches each gave 10.53 tons. With potatoes, 14 inches gave 165 bushels, 10 inches 125 bushels, 6 inches 113 bushels, and no irrigation 49 bushels. The potassium carried to an acre of soil by 2 acre-feet of water, averaged for all streams 33.4 pounds, phosphorus varied from a trace to 30 pounds, and nitrogen averaged 22.8 pounds.

Experiments at the New Mexico station showed that excellent yields of alfalfa could be produced on the mesa lands when sufficient water is used. The data show that cultivation of the soil after irrigation has no effect on the conservation of moisture on this type of soil. With an average annual application of 55 inches on cropped plats water did not penetrate below the reach of the roots of plants. At the Nebraska station, in a study of the cost of irrigation, 1 gallon of fuel furnished power for pumping 13,272 gallons of water from a depth of nearly 40 feet, the cost being 40 cents per acre-inch of water pumped.

In tests made at the Indiana station, angle or straight bar cleats on tractor wheels gave the poorest results, spike forms being best, causing least disturbance of the soil. Tests of the draft of plows at varying speeds, at the Iowa station, showed that there is an increase in draft of from 16 to 25 per cent as the plow speed is increased from 2 to 4 miles per hour. Limestone spreaders with the revolving finger type of distributor gave the most uniform distribution.

At the Wisconsin station, nitro-starch was found well suited for land clearing, being cheaper than dynamite and resisting freezing, but was not adapted to ditch work.

INSULAR EXPERIMENT STATIONS.

The Office of Experiment Stations continued to exercise general supervision over the experiment stations in the insular possessions, which derive their support from direct Federal appropriation to the Department of Agriculture. These stations are located in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands. The relations of the office with them are in immediate charge of W. H. Evans. Separate reports are made upon their operations.

VISITATION OF THE STATIONS.

The examination of the work and expenditures of the stations was carried on as in the past, each continental station receiving Federal funds being visited by a representative of the office during the year. This examination was participated in by five members of the office force—the Chief (E. W. Allen), W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte.

In addition to this personal examination on the ground, the office maintains close relations with the stations through correspondence, passes upon and approves the projects conducted under the Adams fund, and at the close of the year examines the financial reports of the stations before they are formally approved.

STATISTICS OF THE STATIONS.

For the fiscal year ended June 30, 1920, the total income of the experiment stations was \$7,631,254.34, comprising \$1,440,000 Federal funds derived under the Hatch and Adams Acts, \$210,000 Federal appropriations for the insular stations, \$3,594,441.80 State support, \$415,610.48 income from fees, \$1,223,529.20 returns from the sale of products, \$125,916.36 income from miscellaneous sources, and \$621,756.50 carried over as balances from the previous year.

The estimated value of additions to the equipment of the stations during the year was as follows:

Buildings	\$396, 300. 70
Library	21, 033. 34
Apparatus	42, 240. 46
Farm implements	104, 769. 72
Live stock	190, 059. 35
Miscellaneous	497, 082. 60
Total	1, 251, 486. 17

In the work of administration and inquiry the stations employed 1,968 persons, of which 1,137 were also members of the teaching staff of the colleges and 436 assisted in the various lines of extension work.

The statistics of the stations by States are given in detail in the tables following.

TABLE 1.—*General statistics, 1919–20.*

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in extension work.	Publications during fiscal year 1919–20. Number.	Publications during fiscal year 1919–20. Pages.	Number of names on mailing list.
Alabama (College)	Auburn	J. F. Duggar	Feb. —, 1883	Feb. 24, 1888	20	15	11	8	81	25,000
Alabama (Canebrake)	Uniontown	J. M. Burgess	Jan. 1, 1886	Apr. 1, 1888						
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		10	9				
Alaska	Sitka	C. C. Georgeson			9			2	194	4,232
Arizona	Tucson	D. W. Working		—— —, 1889	25	20	7	5	158	11,000
Arkansas	Fayetteville	Bradford Knapp		—— —, 1887	21	20	1	6	90	10,651
California	Berkeley	H. J. Webber	—— —, 1875	Mar. —, 1888	120	97	85	26	836	38,768
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	42	29		4	122	4,700
Connecticut (State)	New Haven	E. H. Jenkins	Oct. 1, 1875	May 18, 1887	19	1		8	684	9,500
Connecticut (Storrs)	Storrs	do		May 18, 1887	12	5	6	5	109	7,000
Delaware	Newark	C. A. McCue		Feb. 21, 1888	14	4	3	3	122	7,000
Florida	Gainesville	P. H. Rolfs		—— —, 1888	11	4	2	13	145	18,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	5			52	156	11,000
Guam	Guam	C. W. Edwards			5			1		2,983
Hawaii	Honolulu	J. M. Westgate			9		2	2	60	2,744
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	38	25	10	34	114	12,248
Illinois	Urbana	Eugene Davenport		Mar. 21, 1888	79	58	50	17	446	42,000
Indiana	Lafayette	G. I. Christie	—— —, 1885	Jan. —, 1888	61	24	3	26	1,005	37,498
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	71	17		25	576	36,000
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	77	51		16	377	11,500
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	54	22	6	8	493	20,000
Louisiana (Sugar)	New Orleans		Sept. —, 1885							
Louisiana (State)	Baton Rouge	W. H. Dalrymple	Apr. —, 1886		23	5	7	6	286	8,578
Louisiana (North)	Calhoun		May —, 1887							
Maine	Orono	C. D. Woods	Mar. —, 1885	Oct. 1, 1887	17			14	432	20,000
Maryland	College Park	H. J. Patterson	—— —, 1888	Apr. —, 1888	31	13		10	199	20,000
Massachusetts	Amherst	F. W. Morse [1]	[2] —— —, 1882	Mar. 2, 1888	46	20		22	596	26,500
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	64	40		20	1,341	45,000
Minnesota	St. Paul (University farm)	R. W. Thatcher	Mar. 7, 1885	—— —, 1888	85	65	5	21	902	11,000
Mississippi	Agricultural College	J. R. Ricks		Jan. 27, 1888	31	14				13,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1818	47	45		24	610	14,576
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		5					
Montana	Bozeman	F. B. Linfield		July 1, 1893	29	17		15	328	11,425
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	37	32	1	9	191	18,400
Nevada	Reno	S. B. Doten		Dec. —, 1887	9	3	1	4	126	6,000
New Hampshire	Durham	J. C. Kendall	—— —, 1886	Aug. 4, 1887	20	18	15	10	140	17,000
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		31	20	28	77	1,341	14,650
New Jersey (College)	do	do		Apr. 26, 1888	16					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	16	12	9	81	249	10,000
New York (State)	Geneva	W. H. Jordan	Mar. —, 1882		38			28	722	42,937
New York (Cornell)	Ithaca	A. R. Mann	—— —, 1879	Apr. —, 1888	59	55	11	15	1,501	2,146
North Carolina (College)	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	46	13		3	151	9,000
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	34	18	6	4	234	10,000
Ohio	Wooster	C. E. Thorne	Apr. 25, 1882	Apr. 2, 1888	52		5	83	1,825	66,560
Oklahoma	Stillwater	H. G. Knight		Dec. 25, 1890	21	17		10	156	6,054
Oregon	Corvallis	J. T. Jardine		July —, 1888	56	38	12	67	522	1,049
Pennsylvania	State College	R. L. Watts		June 30, 1887	70	70	70	12	262	40,000
Pennsylvania (Nutrition)	do	H. P. Armsby	—— —, 1907		7					500
Porto Rico	Mayaguez	D. W. May			9		1	3	56	2,775
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	12	2		12	186	1,775
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	23	12	8	4	158	4,500
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	17	16		6	152	22,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	16	5		2	179	12,000
Texas	College Station	B. Youngblood		Apr. 3, 1889	46	2		38	1,975	48,648
Utah	Logan	F. S. Harris		—— —, 1890	36	27	12	10	293	9,000
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	12	8	1	3	132	2,000
Virginia	Blacksburg	A. W. Drinkard, jr	—— —, 1888	—— —, 1891	24	12	1	3	44	13,000
Virginia (Truck)	Norfolk	T. C. Johnson			6			2	32	6,500
Virgin Islands	St. Croix	L. Smith			2					
Washington	Pullman	E. C. Johnson		—— —, 1891	42	25		5	117	10,508
West Virginia	Morgantown	J. L. Coulter		June 11, 1888	31	22	7	11	76	25,000
Wisconsin	Madison	H. L. Russell	—— —, 1883	—— —, 1887	87	78	49	25	704	44,028
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	13	12	1	7	289	6,000
Total					1,968	1,137	436	927	22,275	933,933

[1] Acting director.
[2] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch station at the same place.

TABLE 2.—*Revenue and*

Station.	Federal.		State.	Balances from previous year.[1]	Fees.	Sales.	Miscellaneous.
	Hatch fund.	Adams fund.					
Alabama (College)	$15,000	$15,000	$27,000.00	$4,535.69	$1,151.02		
Alaska [2]							$75,000.00
Arizona	15,000	15,000	73,171.14	590.29		$25,377.16	
Arkansas	15,000	15,000	18,896.00			7,500.00	
California [3]	15,000	15,000	149,085.40		4,315.96	79,956.51	13,293.39
Colorado	15,000	15,000	91,440.46	43,421.56			
Connecticut (State)	7,500	7,500	35,000.00	9.76	10,019.33		15,100.70
Connecticut (Storrs)	7,500	7,500	12,625.00	4,034.49			14,316.61
Delaware	15,000	15,000	10,000.00			24,306.91	
Florida	15,000	15,000	8,736.99	4,173.47		5,822.39	
Georgia	15,000	15,000	8,748.92	2,531.20		13,509.37	
Guam [2]							20,000.00
Hawaii [2]							50,000.00
Idaho	15,000	15,000	27,149.98	971.96		2,691.18	
Illinois	15,000	15,000	195,500.00	25,350.63		73,503.09	
Indiana	15,000	15,000	91,000.00	106,750.53	141,737.82	137,247.65	
Iowa	15,000	15,000	222,750.00	9,012.91		53,717.42	
Kansas	15,000	15,000	93,800.00	18,338.74		60,179.39	
Kentucky	15,000	15,000	50,000.00	61,224.36	123,576.03	35,117.09	4,101.33
Louisiana	15,000	15,000	26,541.70			6,441.68	11,673.11
Maine	15,000	15,000	15,000.00			18,001.44	18,753.88
Maryland	15,000	15,000	32,167.47			22,030.37	
Massachusetts	15,000	15,000	55,875.80	16,834.83	10,925.79	5,530.79	2,177.79
Michigan	15,000	15,000	104,970.14		23,468.82	8,572.44	2,689.33
Minnesota	15,000	15,000	257,173.10			82,842.78	1,256.65
Mississippi	15,000	15,000	32,366.66	15,696.18	243.00	20,256.76	325.96
Missouri (College)	15,000	15,000	24,174.97	19,165.57	38,971.45	25,887.29	
Montana	15,000	15,000	110,517.60			27,342.42	
Nebraska	15,000	15,000	101,703.04	36,798.87		66,838.16	
Nevada	15,000	15,000		523.13		317.49	
New Hampshire	15,000	15,000		432.88		4,186.28	12,765.24
New Jersey (State)			89,392.30		48,780.94	33,813.17	
New Jersey (College)	15,000	15,000					
New Mexico	15,000	15,000	7,500.00	13,071.04		6,323.29	
New York (State) [4]	1,500	1,500	146,195.71	5,064.06			
New York (Cornell)	13,500	13,500	109,022.46		12,420.32	14,837.22	2,896.67
North Carolina	15,000	15,000	112,150.00	4,425.97		7,793.08	
North Dakota	15,000	15,000	69,432.81	24,411.93		58,186.53	4,850.00
Ohio	15,000	15,000	279,035.00	124,101.67		56,674.75	
Oklahoma	15,000	15,000	10,000.00	6,212.43		8,909.94	
Oregon	15,000	15,000	86,500.00	27,867.33		18,533.29	2,000.00
Pennsylvania	15,000	15,000	2,330.57				
Porto Rico [2]							50,000.00
Rhode Island	15,000	15,000		1,916.00			6,288.10
South Carolina	15,000	15,000	24,371.09	3,857.44		3,047.61	
South Dakota	15,000	15,000	13,500.00	11,426.94		4,449.09	11,932.89
Tennessee	15,000	15,000	51,939.73			15,974.91	
Texas	15,000	15,000	213,540.00	2,109.11		77,616.76	
Utah	15,000	15,000	48,084.61	2,867.19		19,454.13	
Vermont	15,000	15,000		1,142.46			
Virgin Islands [2]							15,000.00
Virginia	15,000	15,000	39,450.00	13,156.53		21,349.67	1,494.73
Washington	15,000	15,000	186,576.15	5,837.27		43,043.21	
West Virginia	15,000	15,000	67,500.00	2,025.09		21,939.87	
Wisconsin	15,000	15,000	162,527.00				
Wyoming	15,000	15,000		1,866.96		4,406.62	
Total	720,000	720,000	3,594,441.80	621,756.50	415,610.48	1,223,529.20	335,916.36

[1] Not including balances from Federal funds.
[2] Federal appropriation.

additions to equipment, 1920.

Total.	Additions to equipment.						
	Buildings.	Library.	Apparatus.	Farm implements.	Live stock.	Miscellaneous.	Total.
$62,686.71	$100.00	$400.00	$600.00	$400.00	...	$600.00	$2,100.00
75,000.00	...	...	...	...	...	...	...
129,138.59	10,968.47	5.14	853.12	3,105.15	$6,522.90	639.16	22,093.94
56,396.00	...	...	851.31	1,463.69	37.00	27,648.00	30,000.00
276,651.26	13,554.89	664.49	1,590.16	4,106.85	10,903.17	2,014.03	32,833.59
164,862.02	...	1,505.00	3,960.00	1,675.00	6,504.00	2,250.00	15,894.00
75,129.79	2.48	477.49	4.75	2,145.43	16.50	301.83	2,948.48
45,976.10	628.03	84.75	334.64	322.90	1,174.75	...	2,545.07
64,306.91	...	101.28	1,272.29	3,060.06	8,518.60	36.02	12,988.25
48,732.85	754.81	470.37	242.80	803.19	572.30	570.60	3,414.07
54,789.49	...	331.60	772.19	1,356.70	1,442.22	6,821.89	10,724.60
20,000.00	...	...	...	...	...	...	...
50,000.00	...	...	...	...	...	...	...
60,813.12	3,400.00	50.00	1,400.00	350.00	2,300.00	825.00	8,325.00
324,353.72	1,139.35	...	...		...	21,000.80	22,140.15
506,736.00	9,334.30	1,065.35	307.82	812.24	31,307.98	393,563.99	436,391.68
315,489.33	...	...	...	...	...	...	...
202,318.13	11,000.00	500.00	500.00	6,500.00	8,500.00	1,000.00	28,000.00
304,018.81	15,048.66	1,159.47	1,289.26	1,141.25	6,131.95	185.32	24,955.91
74,656.49	1,140.16	94.52	741.61	2,272.07	1,183.39	...	5,431.75
81,755.30	...	...	...	...	...	...	...
84,197.84	506.03	1,031.67	1,816.09	...	744.71	...	4,098.50
121,345.00	1,124.22	873.08	236.02	957.87	15.00	...	3,206.19
169,700.73	...	...	...	...	...	...	...
371,272.53	12,600.00	1,025.00	1,550.00	4,400.00	8,000.00	...	27,575.00
98,888.56	4,225.00	13.50	20.00	5,257.00	21,311.40	4,362.13	35,189.03
138,199.28	2,705.64	39.72	1,753.50	237.61	4,727.65	870.52	10,334.64
167,860.02	...	400.00	700.00	1,300.00	3,200.00	300.00	5,900.00
235,340.07	50,000.00	1,092.22	3,351.26	4,766.83	5,991.81	...	65,202.12
30,840.62	1,097.07	63.13	169.67	377.85	1,556.51	436.17	3,700.40
47,384.40	324.60	208.37	216.57	408.31	...	...	1,157.85
171,986.41	...	...	...	...	...	...	...
30,000.00	1,099.84	549.78	2,969.33	318.20	1,400.00	1,645.25	7,982.40
56,894.33	1,060.87	12.92	466.23	721.55	1,967.12	20.05	4,248.74
154,259.77	2,312.98	...	...		...	...	2,312.98
166,176.67	5,831.18	488.85	1,156.83	1,913.19	61.50	6,625.31	16,076.86
154,369.05	1,614.60	592.34	...	350.00	50.00	77.70	2,684.64
186,881.27	2,700.00	100.00	1,200.00	4,025.00	5,090.00	...	13,115.00
489,811.42	2,862.47	2,255.49	979.10	495.00	3,175.70	11,642.84	21,410.60
55,122.40	...	...	...	...	600.00	...	600.00
164,900.62	...	58.54	1,764.16	9,887.75	970.00	2,310.48	14,990.93
32,330.57	...	850.00	300.00	1,500.00	10,107.25	...	12,757.25
50,000.00	1,495.77	112.54	13.50	294.30	275.00	118.95	2,310.06
38,204.10	52.62	163.23	14.31	84.35	104.40	6.85	425.76
61,276.14	12,000.00	400.00	1,000.00	15,000.00	11,000.00	100.00	39,500.00
71,308.92	1,900.00	200.00	750.00	1,500.00	380.00	...	4,730.00
97,914.64	7,605.90	630.00	404.43	1,956.58	...	571.60	11,168.51
323,265.87	14,630.85	1,627.50	3,994.25	7,789.72	2,800.00	6,952.63	37,794.95
100,405.93	100,000.00	366.41	1,092.07	1,116.46	6,581.38	695.85	109,852.17
31,142.46	...	...	...	...	...	...	...
15,000.00	400.00	21.00	...	277.66	28.85	...	727.51
105,450.93	10,451.56	119.61	85.30	1,056.88	2,521.15	...	14,234.80
265,456.63	82,340.73	283.95	1,274.12	8,513.49	8,410.50	2,371.92	103,194.71
121,464.96	...	...	...	...	...	...	...
192,527.00	...	...	...	...	...	...	...
36,273.58	8,287.62	545.03	243.77	749.59	3,874.66	517.71	14,218.38
7,631,254.34	396,300.70	21,033.34	42,240.46	104,769.72	190,059.35	497,082.60	1,251,486.17

[3] The resources from other than Federal funds are estimated.
[4] Including balances from previous year: $11.81 Hatch and $2.50 Adams.

TABLE 3.—*Expenditures from United States appropriations received*

Station.	Amount of appropriation.	Classified						
		Salaries.	Labor.	Publications.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.
Alabama	$15,000	$7,700.00	$3,261.91	$877.62	$481.51	$80.26	$38.50	$18.66
Arizona	15,000	12,798.39	280.35	50.00	233.59	30.48	64.00	99.33
Arkansas	15,000	8,338.37	963.90	891.76	213.87	130.68	169.41	112.78
California	15,000	15,000.00						
Colorado	15,000	12,073.62	1,009.95	84.50	62.76	31.79		91.08
Connecticut (State)	7,500	7,500.00						
Connecticut (Storrs)	7,500	7,500.00						
Delaware	15,000	9,010.08	1,786.55	2,235.30	817.72	81.24	89.72	19.50
Florida	15,000	8,330.00	1,759.49	1,297.85	828.00	102.29	280.08	13.23
Georgia	15,000	6,158.37	2,646.66	264.96	372.41	201.53	659.28	575.24
Idaho	15,000	10,507.87	2,040.26	238.97	72.75	43.87	42.50	287.66
Illinois	15,000	13,364.93	753.59	843.10	22.93			5.05
Indiana	15,000	12,912.83	1,743.55		3.09			
Iowa	15,000	8,241.25	276.00	776.12	386.93	135.23	125.72	15.08
Kansas	15,000	8,893.35	5,031.47	8.00	164.49	6.48		28.96
Kentucky	15,000	14,819.83		47.17				
Louisiana	15,000	6,998.25	4,011.39	1,105.36	239.80	79.82	359.51	7.50
Maine	15,000	8,068.25	1,042.75	195.04	608.96	148.11	598.29	4.12
Maryland	15,000	12,554.05	1,956.70	105.43	13.89	123.53	58.67	2.60
Massachusetts	15,000	14,081.50	918.50					
Michigan	15,000	14,985.45						
Minnesota	15,000	15,000.00						
Mississippi	15,000	8,926.81	2,402.76		19.91	125.60		
Missouri	15,000	9,107.63	1,498.09		206.76	299.89	79.59	195.70
Montana	15,000	9,085.02	1,701.15	1,969.41	416.98	44.85	87.83	514.65
Nebraska	15,000	6,449.97	3,864.46	2,034.68	55.95	7.80		64.20
Nevada	15,000	8,601.47	1,693.32	250.59	194.08	46.59	310.96	85.85
New Hampshire	15,000	8,937.05	1,392.84	1,778.99	573.00	236.95	606.27	37.96
New Jersey	15,000	9,599.98	1,875.07	203.68	265.02	23.43		305.76
New Mexico	15,000	5,899.24	4,019.68	1,368.73	84.70	143.06	139.82	140.50
New York (State)[1]	1,500	874.77	359.88		38.14	16.49		
New York (Cornell)	13,500	7,730.00	3,271.16		53.24	17.50	72.80	295.45
North Carolina	15,000	9,692.20	1,535.86		301.98	78.08		
North Dakota	15,000	14,837.51			6.09	13.21		2.46
Ohio	15,000	6,130.37	1,067.71		165.49	213.05	13.07	394.86
Oklahoma	15,000	9,286.81	1,066.20	677.88	492.85	12.79		570.02
Oregon	15,000	11,524.58	305.65	1,130.10	58.65	14.90		516.08
Pennsylvania	15,000	12,056.63	345.40	740.66	97.29	102.83		19.55
Rhode Island	15,000	7,614.38	3,931.64	289.99	187.37	255.26	363.83	93.20
South Carolina	15,000	7,558.36	3,514.53	280.76	584.37	91.91	38.65	16.65
South Dakota	15,000	8,119.26	2,366.10	1,980.55	79.91	152.27	3.60	5.80
Tennessee	15,000	9,896.73	1,004.56	88.29	423.46	97.88	591.64	10.80
Texas	15,000	11,120.92	2,041.61		180.36	43.66	22.00	204.16
Utah	15,000	9,775.35	2,511.56	65.44	48.25	33.78	109.03	80.75
Vermont	15,000	7,488.23	1,856.73	1,507.06	274.66	95.81	1,218,99	34.37
Virginia	15,000	9,629.79	3,179.89	2.50	262.51	101.12	539.69	2.60
Washington	15,000	9,485.67	3,353.03		32.10	5.32	12.15	7.44
West Virginia	15,000	11,386.94	2,126.35		50.10	66.36		146.19
Wisconsin	15,000	11,871.23	1,517.89	126.07	15.37	2.93	146.79	233.60
Wyoming	15,000	6,472.75	4,270.80	417.18	2.50	39.31	137.94	2.90
Total	720,000	484,025.94	87,556.94	23,933.74	9,693.79	3,577.94	6,980.33	5,262.29

[1] Including balance of $11.81.

under act of March 2, 1887 (Hatch Act), for the year ended June 30, 1920.

expenditures.

Seeds, plants, and sundry supplies.	Fertilizers.	Feeding stuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Buildings and repairs.	Balances.
$207.50	$378.51	$388.63	$397.65	$408.85	$622.61	$33.55	....	$15.08	....	$89.16	......
398.40	51.05	....	2.04	3.60	12.55	109.09	....	793.45	....	73.68	......
947.92	51.12	1,283.00	....	1,232.36	20.56	371.58	$37.00	235.69	....	....	......
....	....	....	....	....	....	....	....	....	....	....	......
171.54	....	184.90	53.01	11.71	407.80	154.37	95.50	541.47	$26.00	....	......
....	....	....	....	....	....	....	....	....	....	....	......
....	....	....	....	....	....	....	....	....	....	....	......
349.81	6.95	....	78.80	35.14	25.61	19.95	....	347.13	16.50	50.00	......
151.59	9.31	1,343.40	453.93	126.59	41.40	1.75	....	121.94	20.00	119.15	......
490.07	829.85	1,030.10	174.22	1,146.16	88.30	40.03	....	269.82	20.00	33.00	......
174.38	17.00	658.08	14.00	20.00	....	168.56	....	641.20	25.00	47.90	......
....	....	....	....	....	....	....	....	10.40	....	....	......
2.50	....	223.00	....	14.95	.40	....	....	98.88	....	.80	......
995.82	62.90	3,711.80	....	104.71	8.21	....	....	160.23	....	....	......
288.79	....	28.20	....	303.70	....	6.00	....	221,41	8.00	11.15	......
....	....	....	....	....	....	....	133.00	....	....	....	......
834.09	....	431.09	2.77	355.92	8.75	....	20.00	72.19	....	473.56	......
705.87	830.89	1,912.09	40.27	125.87	204.82	46.19	....	339.62	....	128.86	......
91.26	....	....	81.67	12.20	....	....	....	....	....	....	......
....	....	....	....	....	....	....	....	....	....	....	......
....	....	....	....	....	14.55	....	....	....	....	....	......
....	....	....	....	....	....	....	....	....	....	....	......
166.87	....	2,591.17	....	....	....	....	758.19	....	....	8.69	......
536.02	....	2,553.67	....	33.13	83.03	90.00	85.15	103.56	....	127.78	......
230.22	....	389.00	36.67	203.80	26.01	130.60	....	147.25	....	16.56	......
148.13	....	2,187.21	....	....	....	....	....	187.60	....	....	......
456.65	....	217.58	51.97	847.09	33.75	10.70	399.48	1,109.94	....	689.98	......
254.85	28.00	136.08	208.37	324.71	10.45	40.51	....	409.37	....	24.60	......
406.42	3.92	....	52.15	66.15	180.77	40.60	....	1,627.21	....	349.84	......
263.11	32.28	1,269.29	....	459.92	11.90	8.25	975.00	18.27	.90	165.35	......
20.70	....	....	....	110.40	....	....	....	10.51	....	68.60	$0.51
1,106.93	157.19	....	....	245.50	55.10	143.21	....	351.92	....	....	......
....	1,341.88	2,000.00	....	....	....	....	50.00	....	....	....	......
125.23	13.50	....	....	2.00	....	....	....	....	....	....	......
579.82	634.28	2,170.62	750.00	2,283.33	....	128.90	....	....	....	513.50	......
573.05	....	1,368.80	101.75	407.67	76.75	49.23	114.50	133.43	....	68.27	......
41.00	....	....	10.54	135.00	559.10	93.56	....	591.71	5.00	14.13	......
621.40	587.14	....	....	156.18	4.75	....	....	268.17	....	....	......
511.57	337.31	861.40	229.13	87.86	....	8.76	17.85	18.68	1.40	190.37	......
372.79	650.93	1,235.73	87.44	263.67	134.41	....	....	126.26	....	43.54	......
450.36	....	856.55	48.88	454.83	30.00	205.38	....	232.26	....	14.25	......
556.63	30.00	81.08	315.95	733.25	494.40	....	....	110.19	....	565.14	......
162.10	....	90.65	41.50	605.65	....	91.48	295.00	....	20.00	80.91	......
435.46	....	967.19	241.49	123.43	225.22	3.50	....	176.25	15.00	188.30	......
508.21	31.98	441.18	263.50	8.66	268.24	5.00	....	398.74	....	598.64	......
376.21	336.63	....	15.76	257.98	7.48	....	....	246.40	20.00	21.44	......
525.36	106.49	13.40	....	156.47	326.15	2.50	....	966.52	....	7.50	......
91.71	272.10	....	....	13.52	....	68.43	....	778.30	....	....	......
172.85	99.88	....	....	140.08	59.06	507.84	....	106.41	....	....	......
234.77	....	2,875.21	....	132.78	7.25	....	....	110.48	....	296.13	......
15,737.96	6,901.09	33,500.10	3,753.46	12,109.82	4,049.38	2,579.52	2,980.67	12,097.94	117.80	5,080.78	0.51

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TABLE 4.—*Expenditures from United States appropriations received under the*

Station.	Amount of appropriation.	Classified						
		Salaries.	Labor.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.	Seeds, plants, and sundry supplies.
Alabama	$15,000	$10,433.80	$1,594.14	$57.82	$186.95	$94.10	$375.70	$84.93
Arizona	15,000	11,505.66	296.35	150.79	47.87	....	275.38	159.36
Arkansas	15,000	9,408.80	1,780.56	44.86	117.73	141.70	495.79	522.05
California	15,000	8,461.62	2,018.44	28.11	17.22	2.10	549.34	557.74
Colorado	15,000	12,304.84	628.37	56.72	5.35	....	185.80	98.64
Connecticut (State)	7,500	5,985.82	276.97	58.90	40.63	350.94	138.07	192.73
Connecticut (Storrs)	7,500	7,500.00	....	....	....	....	....	....
Delaware	15,000	10,873.76	484.82	3.90	12.14	121.07	1,668.58	42.58
Florida	15,000	9,441.09	1,697.91	95.59	99.06	60.94	418.70	250.97
Georgia	15,000	9,589.58	975.69	23.58	147.16	206.46	324.97	212.74
Idaho	15,000	11,196.21	1,553.76	6.00	99.16	1.25	608.64	313.29
Illinois	15,000	13,572.70	754.00	7.93	4.62	....	177.26	....
Indiana	15,000	11,058.38	1,114.02	89.84	....	....	234.20	271.28
Iowa	15,000	7,961.43	2,877.37	272.44	6.72	348.00	1,486.40	727.23
Kansas	15,000	9,108.33	3,830.57	13.26	4.05	22.75	730.62	310.07
Kentucky	15,000	13,138.35	330.60	30.30	6.04	41.17	62.86	103.85
Louisiana	15,000	11,173.15	400.00	39.39	70.50	301.73	1,010.26	153.08
Maine	15,000	9,999.96	2,032.67	61.25	116.28	289.18	23.58	223.44
Maryland	15,000	11,712.02	329.32	21.97	....	....	655.23	404.20
Massachusetts	15,000	14,448.31	272.00	....	....	....	4.58	58.89
Michigan	15,000	15,000	....	....	....	....	....	....
Minnesota	15,000	15,000	....	....	....	....	....	....
Mississippi	15,000	10,257.40	2,959.81	20.09	40.77	266.07	....	247.10
Missouri	15,000	6,292.38	1,990.40	32.19	229.25	117.44	498.50	373.08
Montana	15,000	12,881.44	500.35	40.86	48.83	16.42	679.37	66.24
Nebraska	15,000	10,799.96	1,387.74	....	24.84	....	184.79	543.85
Nevada	15,000	9,296.45	2,154.02	2.65	44.95	....	281.66	171.43
New Hampshire	15,000	11,367.41	2,033.10	26.82	22.37	4.91	143.35	396.93
New Jersey	15,000	10,836.08	973.42	65.32	38.95	10.55	569.51	454.56
New Mexico	15,000	9,801.01	2,757.99	12.07	115.75	408.86	547.63	469.03
New York (State) [1]	1,500	1,356.07	....	....	....	....	56.65	....
New York (Cornell)	13,500	12,100.00	415.24	101.38	....	....	236.58	200.54
North Carolina	15,000	15,00.00	....	....	....	....	....	....
North Dakota	15,000	11,580.69	175.35	....	13.87	....	368.05	51.82
Ohio	15,000	8,878.13	2,496.85	26.89	31.79	....	1,124.05	162.56
Oklahoma	15,000	11,104.15	1,952.79	59.28	4.09	19.68	93.62	190.22
Oregon	15,000	13,850.00	54.28	5.00	25.55	22.26	746.94	147.02
Pennsylvania	15,000	11,867.86	674.49	38.06	22.27	....	286.37	208.87
Rhode Island	15,000	8,819.03	3,471.95	52.91	5.62	254.00	302.84	127.52
South Carolina	15,000	11,457.03	1,273.31	16.71	57.62	15.28	574.69	246.26
South Dakota	15,000	9,260.87	2,838.41	1.65	78.72	....	155.37	625.44
Tennessee	15,000	11,739.54	647.10	45.35	120.23	323.26	960.70	129.46
Texas	15,000	9,482.16	2,117.49	53.27	143.78	....	1,453.68	340.73
Utah	15,000	9,775.60	3,858.71	1.64	108.98	39.43	368.41	358.64
Vermont	15,000	10,069.82	1,583.86	39.12	33.18	5.99	74.99	210.03
Virginia	15,000	10,437.50	2,574.34	....	71.89	1.32	295.53	231.26
Washington	15,000	11,606.08	1,870.90	13.47	....	....	311.55	340.98
West Virginia	15,000	11,493.35	674.32	....	.66	45.15	798.59	324.62
Wisconsin	15,000	8,967.50	3,346.88	5.75	4.04	132.36	111.47	400.17
Wyoming	15,000	9,825.52	1,640.40	6.78	79.20	125.74	1,055.82	98.68
Total	720,000	529,076.84	69,671.06	1,729.91	2,348.68	3,790.11	21,706.67	11,804.11

[1] Including balance of $2.50.

t of March 16, 1906 (Adams Act), for the year ended June 30, 1920.

xpenditures.

Ferti-lizers.	Feeding stuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Buildings and repairs.	Balances.
$174.15	$779.05	$42.25	$43.97	$56.68	$641.44	....	$351.22	....	$83.80	......
....	....	2.10	226.99	135.55	736.53	....	750.80	$1.40	711.22	......
288.03	629.66	....	231.33	312.03	479.73	....	547.73	....	....	......
....	325.44	20.46	357.73	390.64	200.20	$300.00	1,510.68	....	260.28	......
11.69	7.30	....	....	745.55	420.19	....	225.00	....	310.55	......
113.04	204.46	....	26.67	4.20	1.00	....	104.07	2.50	....	......
....	....	....	....	....	....	....	....	....	....	......
144.10	....	22.44	45.30	....	1,252.34	....	228.96	....	100.00	$0.01
584.71	....	14.57	152.81	162.25	241.05	....	1,542.39	....	237.96	......
....	2,511.65	54.75	74.65	....	14.15	658.72	204.65	....	1.25	......
....	127.50	....	154.78	....	313.70	100.00	328.81	....	196.90	......
....	228.46	....	47.79	66.39	....	39.00	101.85	....	....	......
144.44	194.96	215.13	329.60	83.48	307.82	706.84	250.01	....	....	......
30.40	432.40	....	187.49	6.95	478.62	10.25	30.55	....	143.75	......
.65	308.29	....	205.04	6.77	21.25	96.50	35.00	....	306.85	......
....	491.45	13.23	28.60	....	465.22	229.00	59.33	....	....	......
....	225.63	83.25	2.75	92.25	741.61	10.50	674.65	....	21.25	......
....	1,628.99	136.65	....	121.75	26.96	....	275.81	....	63.48	......
....	....	6.75	269.54	415.04	1,019.09	....	11.51	.75	154.58	......
216.22	....	....	....	....	....	....	....	....	....	......
....	....	....	....	....	....	....	....	....	....	......
....	....	....	....	....	....	....	....	....	....	......
....	265.00	25.90	73.50	....	742.04	....	102.32	....	....	......
28.00	3,861.01	6.00	2.25	....	1,391.31	4.50	78.79	....	94.90	......
....	....	41.95	8.35	33.40	201.12	....	481.67	....	....	......
....	494.96	63.00	1.37	49.00	756.37	366.77	327.35	....	....	......
....	1,467.79	8.00	43.00	23.60	31.67	1,167.38	307.40	....	....	......
105.00	164.88	....	83.60	35.00	176.06	....	140.57	....	300.00	......
3.13	360.00	117.70	252.05	35.26	112.00	250.00	....	4.75	750.00	166.72
4.67	56.71	4.51	133.15	8.15	454.23	50.00	....	....	176.24	......
....	....	....	....	....	52.50	....	....	....	....	34.78
....	....	....	203.83	....	242.43	....	....	....	....	......
....	....	....	....	....	....	....	....	....	....	......
....	787.60	....	568.02	....	....	1,454.60	....	....	....	......
....	245.88	588.03	451.84	....	745.23	213.92	....	....	34.83	......
72.50	526.33	61.00	67.82	110.74	313.09	355.78	68.91	....	....	......
....	....	....	....	....	134.95	....	....	....	14.00	......
....	....	134.69	5.20	....	945.25	....	66.94	....	750.00	......
....	1,730.69	2.80	66.08	....	9.66	88.85	....	3.15	64.90	......
364.32	110.40	37.44	79.50	29.86	721.38	....	3.50	....	12.70	......
28.48	549.38	78.17	28.75	73.00	655.30	244.00	382.46	....	....	......
....	....	114.07	118.25	60.10	404.43	....	127.13	....	210.38	......
....	17.55	15.25	215.92	201.99	480.02	99.25	39.63	....	339.28	......
....	....	....	64.43	17.50	261.17	....	145.49	....	....	......
7.85	597.79	11.00	1.75	19.33	1,042.46	165.00	387.83	....	750.00	......
40.10	960.99	....	41.15	2.20	6.65	....	212.07	....	125.00	......
....	....	....	2.70	69.50	579.62	....	205.20	....	....	......
54.80	198.45	....	140.60	85.75	800.86	90.00	292.85	....	....	......
1.73	1,777.72	4.15	152.39	.70	30.00	....	62.44	....	2.70	......
....	1,299.32	45.03	357.05	....	243.77	111.25	106.89	....	4.55	......
18.01	23,567.69	1,970.27	5,547.59	3,454.61	18,894.47	6,812.11	10,772.46	12.55	6,221.35	201.51

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906.

State or Territory.	Hatch Act.		Adams Act.	
	1888–1919	1920	1906–1919	1920
Alabama	$478,956.42	$15,000.00	$176,619.89	$15,000.0
Arizona	444,803.10	15,000.00	179,955.61	15,000.0
Arkansas	478,139.12	15,000.00	179,900.00	15,000.0
California	480,000.00	15,000.00	179,926.84	15,000.0
Colorado	479,718.82	15,000.00	178,638.93	15,000.0
Connecticut	480,000.00	15,000.00	180,000.00	15,000.0
Dakota Territory	56,250.00	....	....	....
Delaware	478,382.87	15,000.00	175,475.12	15,000.0
Florida	479,966.06	15,000.00	179,996.06	15,000.0
Georgia	475,593.43	15,000.00	167,092.87	15,000.0
Idaho	404,324.13	15,000.00	175,842.22	15,000.0
Illinois	479,564.95	15,000.00	179,851.62	15,000.0
Indiana	479,901.19	15,000.00	180,000.00	15,000.0
Iowa	480,000.00	15,000.00	180,000.00	15,000.0
Kansas	479,995.00	15,000.00	180,000.00	15,000.0
Kentucky	479,996.57	15,000.00	180,000.00	15,000.0
Louisiana	480,000.00	15,000.00	180,000.00	15,000.0
Maine	479,999.62	15,000.00	180,000.00	15,000.0
Maryland	479,967.40	15,000.00	179,236.48	15,000.0
Massachusetts	479,617.70	15,000.00	180,000.00	15,000.0
Michigan	479,676.10	15,000.00	176,341.20	15,000.0
Minnesota	479,917.78	15,000.00	179,345.00	15,000.0
Mississippi	480,000.00	15,000.00	180,000.00	15,000.0
Missouri	475,097.24	15,000.00	179,999.90	15,000.0
Montana	390,000.00	15,000.00	177,417.04	15,000.0
Nebraska	479,932.16	15,000.00	180,000.00	15,000.
Nevada	479,214.32	15,000.00	178,180.28	15,000.
New Hampshire	480,000.00	15,000.00	180,000.00	15,000.
New Jersey	479,949.97	15,000.00	179,558.78	15,000.
New Mexico	444,509.05	15,000.00	180,000.00	15,000.
New York	479,777.75	14,988.19	179,500.53	14,997.
North Carolina	480,000.00	15,000.00	165,000.00	15,000.
North Dakota	421,502.26	15,000.00	179,638.85	15,000.
Ohio	480,000.00	15,000.00	178,514.02	15,000.
Oklahoma	404,568.96	15,000.00	161,360.56	15,000.
Oregon	465,156.64	15,000.00	175,000.00	15,000.
Pennsylvania	479,967.43	15,000.00	179,995.41	15,000.
Rhode Island	480,000.00	15,000.00	177,464.20	15,000.
South Carolina	479,542.15	15,000.00	178,460.12	15,000.
South Dakota	423,250.00	15,000.00	175,000.00	15,000.
Tennessee	480,000.00	15,000.00	180,000.00	15,00
Texas	480,000.00	15,000.00	177,592.26	15,00
Utah	345,000.00	15,000.00	179,821.94	15,00
Vermont	480,000.00	15,000.00	180,000.00	15,00
Virginia	477,824.12	15,000.00	179,949.01	15,00
Washington	417,102.65	15,000.00	176,080.11	15,00
West Virginia	479,968.71	15,000.00	177,859.12	15,00
Wisconsin	480,000.00	15,000.00	180,000.00	15,00
Wyoming	465,000.00	15,000.00	180,000.00	15,00
Total	22,422,133.67	719,988.19	8,554,613.97	719,99

UNITED STATES DEPARTMENT OF AGRICULTURE

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1921

PREPARED BY THE
OFFICE OF EXPERIMENT STATIONS
STATES RELATIONS SERVICE

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1923

STATES RELATIONS SERVICE.

A. C. TRUE, Director.

OFFICE OF EXPERIMENT STATIONS.

E. W. ALLEN, Chief.

RELATIONS WITH INSTITUTIONS FOR AGRICULTURAL RESEARCH.

Supervision of Work and Expenditures of the State Experiment Stations Under Federal Appropriations.

E. W. ALLEN, E. R. FLINT, J. I. SCHULTE, W. H. EVANS, W. H. BEAL.

Experiment Station Record.

E. W. ALLEN, Ph. D, editor; H. L. KNIGHT, B. S., associate editor; SYBIL L. SMITH M. A., agricultural chemistry and agrotechny; W. H. BEAL, A. B., M. E., and R. W TRULLINGER, B. S. C. E., meteorology, soils, and fertilizers; W. H. EVANS, Ph. D., an W. E. BOYD, Ph. B., agricultural botany, bacteriology and plant pathology; H. M. STEECE B. S., field crops; J. W. WELLINGTON, B. S., horticulture and forestry; W. A. HOOKER B. S., D. V. M., economic zoology and entomology; C. F. LANGWORTHY, Ph. D., D. Sc. and SYBIL L. SMITH, M. A., foods and human nutrition; F. J. KELLEY, B. S., animal hus bandry, dairying, and dairy farming; W. A. HOOKER, B. S., D. V. M., and SYBIL L. SMITH M. A., veterinary medicine; R. W. TRULLINGER, B. S. C. E., rural engineering; EUGEN MERRITT, A. B., and LOUISE MARBUT, A. B., rural economics; E. H. SHINN, A. B., B. S. and MARIE T. SPETHMANN, agricultural education; MARTHA C. GUNDLACH, A. B., indexing WILLIAM HENRY, proof reading.

DIVISION OF INSULAR STATIONS.

W. H. EVANS, Ph. D., Chief.

Alaska Experiment Stations.

C. C. GEORGESON, M. S., D. Sc., agronomist in charge, Sitka; G. W. GASSER, B. S assistant in charge, Fairbanks; C. S. HAHN, B. S., M. F., assistant in charge, Rampart F. E. RADER, B. S., assistant in charge, Matanuska; W. T. WHITE, B. S., assistant i charge, Kodiak.

Guam Experiment Station.

C. W. EDWARDS, B. S., animal husbandman in charge, Island of Guam; G. BRIGGS, B. S agronomist and horticulturist; W. J. GREEN, B. S., assistant in agronomy and extensio work; J. GUERRERO, assistant in horticulture; P. NELSON, assistant.

Hawaii Experiment Station.

J. M. WESTGATE, M. S., agronomist in charge, Honolulu; W. T. POPE, M. S., horticu turist; F. G. KRAUSS, superintendent of extension work, Haiku; R. A. GOFF, B. S., exte sion agent, Hilo; H. L. CHUNG, M. S., agronomist; J. C. RIPPERTON, assistant chemist.

Porto Rico Experiment Station.

D. W. MAY, M. Agr., agronomist in charge, Mayaguez; T. B. MCCLELLAND, A. B., hort culturist; W. V. TOWER, B. S., entomologist; L. G. WILLIS, B. S., chemist; THOM BREGGER, B. S., plant breeder; J. O. CARRERO, B. S. Ch. E., assistant chemist; W. SNYDER, B. S., assistant in plant breeding; H. C. HENRICKSEN, B. Agr., specialist in far management, San Juan; J. A. SALDANA, assistant in horticulture.

Virgin Islands Experiment Station.

LONGFIELD SMITH, Ph. D., agronomist in charge, St. Croix; C. E. WILSON, M. entomologist.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
STATES RELATIONS SERVICE,
Washington, D. C., March, 1923.

SIR: I have the honor to transmit herewith a report on the work nd expenditures of the agricultural experiment stations of the Jnited States for the year ended June 30, 1921, in accordance with provision of the act of Congress of March 4, 1915, entitled "An ct making appropriations for the Department of Agriculture for ıe fiscal year ending June 30, 1916." (38 Stat. L., p. 1110.)

Very respectfully,

A. C. TRUE, *Director.*

Hon. HENRY C. WALLACE,
Secretary of Agriculture.

CONTENTS.

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1921.

By E. W. Allen, E. R. Flint, and J. I. Schulte.

The general condition of the agricultural experiment stations began to show some signs of improvement during the year. These were evident chiefly in a changed attitude toward the stations and an apparent realization of the crippled condition which had resulted during the war, with failure to respond to the needs following that period. There was a return of workers who had gone out into commercial enterprises, and a general stimulation of interest in the activities and the welfare of the stations.

While there was practically no increase in financial support in the aggregate, improvement was noticeable in individual cases, and in many others the stations were beginning to be relieved in various ways by their colleges which had benefited by increased appropriations. There was relief in the duties of teaching—if not a reduction in the number having such duties, at least a decrease in the amount required and a more advantageous scheduling of such duties. The colleges were able, through the relief they had received, to exercise a more liberal attitude in this and other respects. The station workers also profited by the increased salary scale entered upon by most institutions, which made the outlook for the future more attractive.

POSITION OF THE STATIONS.

One encouraging feature of the situation was a fuller realization on the part of administrative officers of the hard ways upon which the stations had fallen. For two years the addresses of the retiring presidents of the Association of Land-Grant Colleges have dealt pertinently with the importance of research and the necessity to the other branches of the college of making adequate provision for it. Chancellor Avery, of Nebraska, in the address of 1920, referring to the fact that instead of a return to normal the situation was even worse, declared that " if this condition is not remedied I feel that we are drifting toward sterile times in thought and progress. * * * Only by a radical change in our system can we hope to maintain that degree of efficiency in the work of investigation which till recently was the glory and pride of our colleges." He showed that the demand for such work was increasing, not only along the lines which had been followed in the past, but in many new directions which required the services of the investigator.

Dean H. L. Russell, in his presidential address in 1921, devoted his entire attention to the experiment station, with a vigorous discus-

sion of the difficulties confronting it and the inevitable effects. Calling attention to the changed emphasis in the colleges, following the inauguration of extension work, he said:

Our farmers are by no means standing still in their agricultural processes. Constant advancement in extension work must be made to insure the highest degree of success. Unless research is constantly opening up new facts, new explanations, and new principles, extension teaching will soon sink to a sterile repetition of old material and die of dry-rot. Experimental inquiry is the living spring that vitalizes all other phases of agricultural instruction. If the fountain fails, all other activities languish.

The effects of diminished activity are not wholly immediate, as he well stated:

They will show in the scientific results of the next decade. With the working power of the dollar at present reduced from a pre-war basis a third, if not more, and in comparison with the situation which obtained in 1906 even a still greater reduction, it is obvious that the experiment station is going backward rather than forward in its facilities, while on all sides greater and greater demands are being made on it for additional service.

These citations are sufficient to make it evident that not only the weakened condition but the key position of the stations in relation to future progress, and the broadening character of their field with the necessity that research become more fundamental, are realized by administrative officers, who are bending every effort to meet and correct the situation.

REVENUES OF THE STATIONS.

As in the past, the stations derived their main support from the Federal appropriations and those made by the States. In some cases the latter came in the form of specific appropriations for the use of the stations, while in others it was in the form of an allotment from the general appropriations for the agricultural college. Considerable amounts were frequently derived from the sale of products or from fees for inspection work, but rarely were these a source of net income for research.

The aggregate of the State appropriations for 1921 shows an increase of $192,556 over those for 1920, 24 stations reporting an increase, 18 a decrease, and 8 receiving the same appropriation as in 1920. Four of the stations (Ohio, Texas, Minnesota, and Wisconsin) received over $200,000, 11 stations received from $100,000 to $200,000, 13 from $50,000 to $100,000, 8 from $25,000 to $50,000, 4 from $10,000 to $25,000, 4 had less than $10,000, and 6 had no State aid. Fuller statistics on this and other points will be found in the tables at the end of the report.

The Alabama station received $6,875 from the State for the year and the local experiment fund of $27,000 was continued.

The State appropriations for the Arizona station for 1921 were about $50,000, including funds for a dairy barn, a greenhouse, and some minor buildings.

The Arkansas station received appropriations from the State of $43,074.67, of which $31,072.20 was specified for salaries and $12,002.47 for maintenance. An appropriation of $50,000 was made for the purchase of a tract of land at Scott, near Little Rock.

The California allotments to the station were $147,378.71 for general maintenance, salary, and experiment-station work at Berkeley, Davis, and all substations.

The State funds for the Colorado station for 1921 were $57,800 from the mill levy. In addition the legislature provided a special fund of $17,528.67, which includes $10,000 a year for the grading of perishable market produce and also a pure-seed appropriation of $12,000, available for testing and certifying seed.

The General Assembly of Connecticut increased the State appropriation for the State experiment station at New Haven from $45,000 to $82,000 for the biennium and provided a special appropriation of $10,000 for two years for research and experiments in the causes and prevention of diseases and injuries to the Connecticut tobacco crop, which occur in the field or in preparation for market, and for improving the crop by selection and breeding. With the cooperation of a growers' association a field station was opened and a specialist in tobacco diseases employed.

The Delaware State appropriation for the college farm and the station was increased from $10,000 to $20,000 per year beginning July 1, 1921.

The Florida station received only $5,000 from the State, but will benefit by an appropriation of $60,000 for the next biennium, out of which $10,000 a year was planned to be devoted to the Lake Alfred branch station.

In Idaho the total appropriation to the university for the biennium was $700,000, of which $57,308 was allotted to the experiment station for the biennium, which includes the substations.

The allotment of the Illinois station from the State funds for the year 1920–21 was estimated at $140,000.

The Indiana Legislature increased the State appropriation for the station, providing a levy of two-fifths of a cent on each $100 of taxable property, becoming available in July, 1922. It is expected that this will amount to about $234,600 for 1922–23. In the meantime an appropriation of $100,000 was given in addition to the $75,000 heretofore received. This appropriation is not made for specific purposes and permits large latitude.

The Iowa State appropriations for the station were $140,500, but a net increase of $30,000 per year has been made, of which it is specified that $25,000 shall be used for marketing and rural economics, and $5,000 for truck crops in southeastern Iowa.

The appropriations for the Kansas station included $55,000 for the central station at Manhattan, about $27,000 for the branch stations, and $5,000 for special investigations on contagious abortion.

The present State support of the Kentucky station is $50,000 a year.

The total appropriations for the Louisiana station is $50,000 per year, for the central station at Baton Rouge and the branch stations.

The Maine station received $15,000 support from the State for the year.

The Maryland station received about $54,000 from the State, practically the same as last year.

The total State appropriations for the Massachusetts station for the year were about $83,200.

The income of the Michigan station from the State was $197,013. It receives its support by allotment from a one-fifth-mill tax to the college.

The State support of the Minnesota station for the year was $219,000 with special appropriations of $5,000 for drainage work in cooperation with the Bureau of Public Roads, $5,000 for experiments in making sirup from sweet-corn stalks, and $3,000 for work on soils low in lime.

The income of the Mississippi station for the year from the State was $19,500 for the central station and $75,329.52 for the branch stations.

The State appropriations for the Missouri station for the year include $40,000 of which $10,000 was for soil experiment fields and $10,000 for soil survey. Additional appropriations were made to the college of agriculture as follows: For the new agricultural building, $200,000; a new cattle barn, $25,000; for fitting up a laboratory on the third floor of the horticultural building, $4,000; for repairs to the dairy building, $1,000; and repairs to barns $4,500.

The Montana station received $79,395.51 from the State for the year 1920–21, the amount being increased by the legislature of that year. On account of changing the end of the fiscal year from March 1 to July 1, an appropriation of $24,000 was made to cover the period. In the biennium 1921–1923 the central station will receive $98,700 for the first year and $100,000 for the second. For the branch stations, the Judith Basin substation receives $11,240 the first year and $12,000 the second, the horticultural substation $5,620 and $6,000, the Huntley substation $2,000 and $3,000, and the North Montana substation $19,540 and $20,000, respectively.

The allotment for the Nebraska station was about the same as last year, being $26,074, and for the substations $53,321.

The Nevada station is to receive $2,560 for the biennium.

The New Hampshire station has heretofore received no State support, but the legislature has now appropriated $5,000 for 1921–22 and $7,500 for 1922–23.

The New Jersey State station received $119,162 from State and other sources.

The income of the New Mexico station from the State for the year was $7,500.

The New York State station received an appropriation of $185,829 and the Cornell station an allotment of $192,630 from the college for research.

The North Carolina station had the use during the year of approximately $103,550 from funds of the State department of agriculture for experimental work, being divided into $37,000 for the branch stations, $3,000 for experimental work in agronomy, $8,000 for animal industry, $4,000 for general expenses, $45,000 for salaries, and the balance for minor purposes.

State appropriations for the North Dakota station totaled for the year $103,667.

The Ohio station received a State appropriation of $265,365 for the year.

In Oklahoma the college apportioned $10,500 to the station, an increase of $500 a year over the previous allotment.

The receipts of the Oregon station from State appropriations was $92,750 for the year.

In South Carolina the legislature appropriated $50,000 directly to the station, and it will no longer receive the allotment from Clemson College. This appropriation represents an increase of about two-thirds over the allotment it formerly received from the college. Half of this goes to the two branch stations and six cooperative test farms.

The South Dakota station reports an income of $14,460 from the State.

State appropriations for the Tennessee station amounted to $11,904.27. The west and middle Tennessee branch stations each received $10,000 from the State.

For the Texas station the State appropriations amounted to $220,520 for 1921, being quite specifically itemized.

The Utah station received for the year $53,469. The legislature voted an appropriation for the ensuing biennium of $115,000, in addition to $15,000 as a deficiency appropriation. The appropriations for the substations are included in the above.

The State appropriations for the Virginia station amounted to $38,350.

The Washington station received $87,760 from State appropriations to the college.

The West Virginia State appropriations for the year were $104,787.

The Wisconsin station does not receive a direct and separate appropriation, but derives its support from the appropriation made to the agricultural college. The net expenditures for research work for 1920–21, deducting receipts from sales, were not less than $210,000.

Several of the States made no appropriation for the stations, either directly or indirectly. Taking the revenues as reported above and in the statistical tables at the end of this report, the resources available to the individual stations are seen to vary very widely. While the support in some cases is liberal, in others it is so limited as to require operating on a very narrow margin. The rigid economy necessary at many of the stations largely determines the grade and efficiency of their work, for it affects the kind of investigators they can attract to their staffs and the facilities for study which they are able to provide.

PROJECTS CARRIED ON BY THE STATIONS DURING 1921.

The lines of work under investigation by the State experiment stations in 1921 show a total of 4,770 separate projects, an average of about 95 per station. Of this number 506, or an average of 10 per station, are conducted under the Adams fund, the support frequently being supplemented from other sources. Of the 4,770 projects 52 are administrative, control, or regulatory, leaving 4,718 projects dealing with experimentation and research. To these may be added 147 projects of the insular stations, giving a total of 4,865.

The classified list of these projects, owing to cross references and the fact that in some cases it is necessary to classify the same project under more than one head, contains a total of 5,489 entries.

The classification brings out the following facts as to the prevailing lines into which the station activities fall: Field crops lead with

1,535 projects, under which corn has 189, potatoes 126, wheat 119, rotations 95, cotton 85, oats 78, and alfalfa 71. Horticulture comes next with 808 projects, the principal groups being apples 102, fruits—general 64, vegetable and truck crops 46, grapes 43, tomatoes 39, peaches 38, and orchard management 36. Plant pathology follows with 419 projects, the largest groups being potato diseases 51, apple diseases 27, tomato diseases 26, and cereal diseases—general 23. Economic entomology has 395 projects, with bees 32, miscellaneous 27, insecticides 26, corn insects 16, and apple insects, codling moth, and flies 15 each. Under soils there are 284 projects, including soil fertility 55, soil types 32, soil flora 27, soil nitrogen 21, and soil moisture 20. The next largest subjects are veterinary medicine with 174 projects, rural economics with 172, rural engineering with 159, poultry with 152, and dairy cattle with 151. These are followed by fertilizers and swine, each having 141, botany 124, dairy products 118, feeding stuffs and animal nutrition 117, genetics 106, beef cattle 84, chemistry 82, forestry and sheep 68 each, foods and human nutrition 62, economic zoology 29, bacteriology 25, seeds 23, weeds 15, horses and mules 13, animal husbandry—general 11, agrotechny 7, and meteorology 6.

Grouping the projects broadly, agronomy subjects, including field crops, soils, and fertilizers, total 1,960 projects, or about one-third of the whole; botany and horticulture 932 projects, or about one-sixth; and animal husbandry, including dairying and dairy products, about one-eighth of the total; leaving about three-eighths of the projects on all other subjects.

The number of projects listed by the different stations varies widely, as would naturally be expected, considering the marked difference in revenue. Beyond this, however, the practice with respect to the detail in which the work is divided into projects varies widely, which in turn affects the scope and consequently the number of the projects. For the Federal funds the projects are fairly definite and restricted, but those supported by State funds are sometimes so elastic as to cover quite broad lines of work, rather than a specific investigation, thus tending to reduce the number reported by a station, even though its activities really cover a wide range.

The total number as reported for 1921 marks an increase of more than 500 projects over those reported as in progress in 1920. This is somewhat surprising, especially in view of the financial difficulties confronting most of the stations. Probably, however, too great significance should not be attached to a comparison based merely on an enumeration of project titles. Quite certainly one important factor has been the more complete adoption by the stations of the project system itself. Doubtless, too, the tendency toward greater definiteness in restating projects has resulted in a splitting up of numerous undertakings formerly described in more general terms, with a consequent increase in the total number, but without a corresponding extension of the work actually under way. In still other cases, the addition of new projects without a rigorous weeding out of others in a dormant state would swell the total number.

Each year the project system is becoming more firmly established and progress is being made in making it a catalog of definite research activities.

RELATION OF PROJECTS TO REVENUES.

The number of projects an experiment station is carrying does not express the entire need for investigation in the State, but the list may be taken to represent the best judgment of the station as to the most pressing questions which can be undertaken at the time with the resources at command. The fact that the average number of projects per station amounts to 95, as stated above, indicates the large number of questions which have been singled out as calling for attention and solution. This number of projects is probably too large for most stations unless they are strongly organized and supported, but it represents the attempt to respond to the demand as it is seen.

If the stations were at liberty to shape their project lists according to their resources, they might limit the number and raise the character of the attack on the relatively few which were concentrated upon. But for years they have felt the pressure for assistance in the way of new facts and reliable information, and the need is seen more keenly as time goes on. They attempt to meet the situation by covering as broad a field as their resources will permit, underestimating sometimes the necessary expense which will be involved and the provision which should be made for the projects to grow. It is hard for a station conscious of its duty to curtail its work and to effect economies. When once undertaken, it is not easy to drop a line of study, and its successful pursuit is likely to entail more and more expensive facilities, appliances, and procedure.

Some light may be thrown on the adequacy of the support by a consideration of the approximate cost of projects and the relation between resources and their number. Taking the total resources of the State stations at $7,660,570 as reported, and the total number of active projects for the year at 4,770, it is found that the average allowance per project is slightly more than $1,600. Of course, some projects are larger and some smaller, some are more expensive and some less so, but in the 48 States these variations tend to equalize one another sufficiently so that it may be warranted to speak of the average project and the average requirements.

The above amount is not considered excessive when the overhead and other charges, as well as the salaries of investigators, expense of field and laboratory work, clerical hire, publication of results, and the many other items of expense are included. It is the average of a variety of undertakings and a diversity of conditions. It is supported by the fact that at one station in the central West, which is conspicuous for its activity and the high grade of its work, and which keeps an accurate account of the funds used for investigation, the average amount expended per project was $1,650 during the year concerned. As that State has a wide range of projects, such as is called for in a typical agricultural region, and as its projects range from the usual field and feeding experiments to the more intensive types of investigation, its average may perhaps give a fair indication of the funds needed for a mixed program of successful investigation.

When the various States are considered, however, the amount available per project varies tremendously. It runs as low as $400 at one station, which is in the same general region as the one mentioned above; in others it is $1,000 to $1,200; in another group from $1,500

to $1,600, and in a considerable number from $2,000 to $2,500. Omitting extremes where the conditions are quite unusual, the general maximum is a little over $4,000, and occurs in States which have special substations involving relatively heavy expense compared with the number of projects listed. In other words, the provision made in certain States is ten times what it is in others for the annual support of an average problem selected on the best judgment of the station and its advisers.

It does not follow that the problems in one State are relatively less important for the welfare of agriculture than in another, or that the average problem in one locality is intrinsically more exacting, expensive, or worthy of solution than that of another. The data show, however, that the real situation is not equally realized in different States, or that some States are prepared to do less than others. Figured out on the above basis, the support is not found to be in accordance with the size of the State or the relative importance of agriculture in it. It gives a possible basis for expressing the requirements if the projects pressing for solution are to be adequately carried out.

CHANGING CHARACTER OF STATION WORK.

While there has been scant increase in funds for research, considerable improvement has been effected in strengthening the station activities and redirecting them into more progressive channels. The projects have been revised in many cases. There has been a concentration of lines of effort and the character of the inquiry has been made more intensive. There is a noticeable attempt to go behind the facts gathered in comparative trials and to get at their meaning and their competence or significance as a basis for generalization.

For many years there was a tendency to collect local facts quite largely, often with the attempt to give them a breadth of interpretation and application which it has since been found was not warranted. This is a danger in local experiments which do not take account of the real nature of conditions or make allowance for them in tracing the relation of cause and effect. The easiest form of experimenting is to collect local facts, giving to them merely a local interpretation or generalizing from such mass data. But the limitations of such types of experimenting have become evident, and, except for quite local and even temporary purposes, they fail to meet the requirements for sound information.

For this reason much attention is now being given to prescribing or determining the exact conditions of experiment and attempting to weigh individually the influence of the various factors which go to make up the complex situation found in nature and in practice. This calls for refinement of methods, and along with it provision of laboratory or other facilities which enable larger control. Practically every station now furnishes examples of such refinement of apparatus and appliances on a larger or smaller scale. They are becoming more common every year, and they are one of the reasons why present day experimenting and research are becoming increasingly expensive. The type of inquiry to which they apply attempts

o acquire basic facts, and the locality where these are determined is elatively unimportant in many cases, because, with the conditions nd limitations known, these facts can be given their local applica-ion through relatively simple experiments.

Hence, without neglecting the problems of their locality, practi-ally all the stations are contributing, in proportion to their ability, o the general advancement of knowledge applicable to an entire egion or to the whole country. No station works to itself any more, r solely for its local community, and no station advances the lines in vhich it is interested purely by its own efforts. Each is a national sset, and this fact supplies one of the underlying reasons which ustify national aid. Such aid is often applied to undertakings which re of interstate or regional importance, while local appropriations re frequently restricted in use and the provision of them is less re-ponsive to this type of inquiry.

Gradually, therefore, the conditions are changing, both as to the ypes of activity and as to facilities for meeting the needs of sta-ion work. What once seemed luxurious and elaborate in such facili-ies has become more or less commonplace or accepted as essential n making further advance, and what formerly seemed extremely tech-ical and highly specialized for so practical an institution as an ex-eriment station, has come to lie in the very midst of its field. While he idea of what is practical in agricultural research has greatly roadened, the real purpose of such research has not been lost sight f, and the change from the field to the laboratory or to facilities f special construction has not had the effect of divorcing workers rom interest in the practical aspects of agricultural problems. lather, it is an expression of the nature of their quest and the esire to make the information they supply more complete and more eliable.

SOME EXAMPLES OF INTENSIVE INQUIRY.

As example of this more intensive inquiry it is only necessary to ecall the studies in genetics, using small animals and noneconomic lants as well as those employed in agriculture; investigations of ie nutritive requirements of plants, the toxic effect of combinations, ie supply at different intervals of growth, conducted by means of ater. sand, or other cultures; and the relation of light intensity nd other physiological factors to plant growth. Furthermore, the udies of vitamins and other food accessories with rat colonies and her small animals, the extensive work on the composition and ialities of the proteins in various foods and feeding stuffs, the life story of groups of insects, the noneconomic along with the onomic species, and the description and classification of such oups of fungi as the rusts, without restriction to those known to harmful at the present time—these illustrate the breadth of in-iiry designed to supply a broader basis of information and to tter facilitate economic studies and deductions.

In soil studies dependence on field experiments has given way in irt to elaborate systems of lysimeters and pits at several stations, ith arrangements for studying seepage, fixation, balance of ma-rials. and change of form. One institution has installed an ex-nsive system of such lysimeters during the year, because its studies

had gradually enforced their need, and another has installed a battery of cylinders for studying the relations of fertilizing elements in the growth and functioning of apple trees. In some cases the installation of these special facilities has involved an initial expense of $10,000 to $15,000, and led to large operating expenses because of the nature of the work.

Highly complicated apparatus has been installed for maintaining desired temperatures of air and soil and bringing humidity under control, to aid in the quantitative determination of the physiological factors of plant growth; and similar provisions have been made for controlling environment in the study of plant diseases. The recent installation of apparatus in greenhouses at one of the stations to control air and soil temperatures at will, as a means of studying the reciprocal relations of plants and disease organisms with respect to environmental conditions, has involved an outlay of some $20,000, but has enabled work to be done having importance over wide sections of the country. These facilities mark a new point of view as well as new methods in the study of crop factors in health and disease.

The study of the flow of water and its accurate measurement, the principles of pumping machinery, etc., have necessitated the construction of hydraulic laboratories at a number of institutions far in advance of anything extant a few years ago. In animal feeding the facilities have not been confined to modern stables, spacious sheds, and paddocks for handling large numbers of animals, but special apparatus has been perfected for studying the metabolism of matter and energy, the physiology of food requirements and nutrition processes, and the basis of the theory of animal feeding. The employment of such apparatus has for several years been confined to the Institute of Animal Nutrition in cooperation with the Pennsylvania station, but of late a simplified form has been installed at the New Hampshire station through the assistance of the Carnegie Institution of Washington.

In the interest of investigations pertaining to special industries model working plants have been installed at several institutions. A fully equipped sugar house is maintained at one station for technical studies of the purification and handling of juices; specially equipped creameries and cheese factories have been provided for developing the principles on which the various phases of the art rests; and flour mills have been devised to determine the milling qualities of grains, with laboratories to study the causal relations between varieties, soil moisture, fertilization, etc., and the flour and bread making qualities. One such experimental mill, recently completed in Minnesota at a cost of $85,000, is said to be the most complete example of its kind in the world. At least one State has provided a special building and installed elaborate equipment, at a cost of fully $70,000, for studying experimentally the handling of fruit and fruit by-products, to determine the principles underlying the practical processes of manufacture; and another State is now erecting a large and specially equipped field laboratory for some of its horticultural investigations at a cost of more than $250,000.

The development of these and many similar enterprises, often on an extensive scale and quite highly specialized, evidences a departure

from a limited State view of problems. It expresses the idea of the mutual relationship and interdependence of experiment stations in pushing forward the boundaries of exact knowledge. Their effort in that field, especially in the advanced ranges, is a give-and-take process, in which any one of the participants may often receive quite as much as it gives.

REGIONAL PROBLEMS.

Each State has problems peculiar to its own local conditions, which arise from the types of farming pursued, the staple crops grown, as well as the physical conditions of climate, rainfall, elevation, etc. These conditions naturally vary more the farther States are removed from each other and as physical boundaries are passed which alter the character of the country, with the consequent variation in agricultural practices. There are, however, problems of a more general scope, which are bounded by sectional and regional peculiarities rather than by State lines, and a general review of the work in which the stations are engaged shows that emphasis is laid by whole groups of stations on problems arising from conditions peculiar to their section of the country.

Such larger sectional divisions naturally suggest themselves to one familiar with the country as a whole. There are, for instance, the coastal plains of the Southeast where cotton is one of the leading crops, the fruit sections of the Eastern States, the Corn Belt of the Middle States, the extensive dairy industries of the northern Middle States, the live-stock industries of the Great Plains, the arid regions of the Southwest, the fruit-growing industries of the Pacific coast, and the great Wheat Belt of the Northwest. These, of course, are not bounded by hard and fast lines, but run into and overlap each other extensively, and represent simply the leading feature of each part of the country.

Problems that are connected with such regional conditions lend themselves to cooperative work among the stations of the section, and this common interest in problems might cause the casual observer to think that there was more or less duplication in station work. This, however, is rarely the fact. The life history of an insect pest or a plant disease may vary to a considerable extent with a few degrees of latitude, and data that hold true in one State may be quite inapplicable in another. The same holds true as to varieties of crops best adapted to any region, which may vary with the difference of a few hundred feet of elevation or a few inches, more or less, of rainfall. A number of stations might, therefore, have project titles which to one unfamiliar with conditions might seem to be a duplication of the same work, but as a matter of fact are only apparent duplications made necessary by the different conditions under which the stations are working.

Briefly reviewing some of the more prominent problems of this nature, we find, for instance, in the southeastern stations extensive studies on cotton, including breeding experiments to develop a variety of good yield and suitable staple which will mature sufficiently early to escape or reduce the ravages of the boll weevil. As

a further aid in combating this pest, forage crops and animal industry problems are being studied in order to encourage a more diversified and self-sustaining farming system.

Among the serious diseases affecting cotton which are being studied cooperatively by the southern stations is anthracnose. Special efforts are being made to develop methods for its control, mainly by treating the seed and also by selecting resistant varieties. Most of the stations of this territory are studying the soft-pork problem to find ways of utilizing peanuts as a feed for swine and at the same time producing a firm pork, retaining the characteristic flavor generally prized by consumers in the Southern States which peanut feeding appears to impart. Experiments with the pecan, the peach, the various citrus and other orchard fruits, and with many of the vegetables that thrive in the region are carried on actively. The possibility of profitable expansion along some of these lines in many localities is realized, and the stations are accumulating data regarding the culture of these crops, better control of diseases and insect pests, and the handling and storing of the product. Other activities of the stations in these States include studies to prevent or minimize soil erosion, a serious problem especially throughout the Piedmont section.

Investigations of the experiment stations in the Southwest are largely concerned with problems of range management, dry farming, irrigation, and managing alkali soils. In the extreme South the growing of dates, citrus fruits, and other semitropical fruits is also being studied. Projects are now in progress dealing with the carrying capacity of the range, range improvement, effects of overgrazing, and efforts to combat poisonous plants of the range. The extent to which native desert plants may be used for maintenance of range live stock is being studied, and considerable work is being done to improve range cattle and sheep through the use of pure-bred sires.

Practically all of the stations in that section are engaged in the study of irrigation problems, particularly the available sources of irrigation water, composition of the water to be used, methods of distribution, and the extent to which land may be irrigated without detrimental results. Methods of growing crops in semiarid districts are under investigation, and work is being done to secure the adaptation of crops to dry-farming conditions. Studies of means for counteracting the alkali in soils and for its removal are in progress.

The potato leafhopper, sugar-beet leafhopper, cotton boll worm, grasshopper, and Mexican bean beetle are among the chief insect pests, the control of which stations in the Southwest are studying. Swamp fever of horses and the cattle tick present problems affecting the live-stock industry of the region, in addition to the more general diseases of animals which are under investigation. The adaptation of fruits and vegetables, field crops, forest trees, and ornamentals to the climate and various altitudes of the Southwest, the study of plant diseases, especially of grains and fruits, and methods of their control, as well as the development of immune varieties; and special problems in farm organization and rural economics are among the projects being carried on by the stations in this region.

The stations in the Northwest are naturally largely concerned with problems connected with wheat raising, which includes not only cultural practices, such as the value of summer fallow and rates and dates of planting, but also varieties and diseases and insect pests affecting this crop. The development of hardy fruits and forage crops by breeding and selection is a field that is covered by a number of the stations in this section and has resulted in the introduction of a number of valuable acquisitions. In those sections of the Northwest where corn will not mature the introduction of the sunflower as a silage crop is to a large extent due to the investigations of the experiment stations. In the great fruit section of the Pacific slope of the Northwest, problems relating to this branch of agriculture have received special attention, including such studies as orchard management and fertilization, storage, shipping, the utilization of by-products, the improvement of varieties grown by selection and breeding, and the control of diseases and insects to which they are subject.

In the northern Middle States the dairy industry is a prominent one, and it is perhaps the study of the feeding of dairy cattle and the production and nutritive value of milk and other dairy products that has led a number of these stations, as well as stations in the Northeast, to take up the subject of nutrition, which has in the past few years advanced to such an extent as to almost revolutionize previous theories, both as applied to animals and man. This is, of course, not a regional problem in itself, but its application is somewhat regional, as applied to the utilization of locally grown feeds, a subject that has engaged the attention of a large number of the stations.

Some problems, like hog cholera, contagious abortion, and tuberculosis, are not local or regional, but are applicable to the whole country, and in some cases are world-wide, and the study of such problems is naturally not confined to any particular group of stations.

DUPLICATION IN STATION WORK.

Fear is sometimes expressed that the experiment stations in different States are to a considerable extent duplicating their experiments and investigations. While there is repetition in different sections to test applications to local conditions, and while similar subjects are being studied by several stations to some extent, there is small ground for fear of duplication which is unnecessary and unprofitable. Especially is this the case where the inquiry is along advanced lines. The farther the work gets away from the commonplace the more individualistic it becomes in character. The danger of duplication lies chiefly in the stage where routine methods are being employed, with a purpose which does not reach beyond the local aspects.

The danger of duplication is small indeed in the advanced reaches of inquiry where the individual viewpoint and imagination are involved and where special apparatus and appliances have been evolved as tools in such inquiry. These things guard against duplication and tend toward concentration and specialization. As Chancellor Avery pointed out in his presidential address mentioned above, in

referring to the opportunity for closer cooperation and the carrying on at a relatively few places of special investigations applicabl to the country at large, "there is an opportunity, in view of th demands made upon us, for a wise distribution among the severa stations of some of the problems confronting us rather than tha all should try to do everything in an inadequate way." This in crease in specialization, and provision of the facilities required fo it, is one of the most notable tendencies of the experiment station and carries large promise for the future.

LEGISLATION AFFECTING THE STATIONS.

In Arizona appropriations were formerly made direct to the uni versity and experiment station. The last legislature substituted a mill tax, which goes to the university as a whole. The station budge is made up by consultation of the director and dean and approve by the president and board of regents. A law was passed to pay th owners half the loss from animals dying under the tuberculin test but no funds are available for this purpose. A law was also passe requiring all official seed testing to be done at the station.

In Indiana an act was passed levying a tax of two-fifths of a cen on each $100 of taxable property for the use of the experiment sta tion, and until this becomes available $175,000 annually was appro priated.

The Michigan Legislature passed a bill creating the department o agriculture, to which was transferred all control work formerl handled by the agricultural college.

The Mississippi Legislature provided for establishing a new branc station at Raymond.

A measure was passed by the Montana Legislature providing tha 1½ mills of the State levy of taxes should be for the maintenance o the university, also one providing for a bond issue by the State o $5,000,000, of which $3,750,000 should be used for building and equip ment at the university. Of this amount $1,500,000 was available fc the State college at Bozeman.

The Nebraska Legislature authorized the purchase of antiho cholera serum for resale to farmers and farm bureaus, in lieu c operating the serum plant for that purpose. This dissolves an in junction in the court against the purchase and resale of the serum.

In New York a State employees' pension law, affecting workers a the State station, became effective January 1, 1921. This provid for voluntary retirement at 60 and compulsory retirement at 70 year The amount of pension is determined by length of service and sala at time of retirement, but can in no case exceed half the salary a retirement.

Under an act of the Ohio Legislature, passed April 19, 1921, which a general reorganization of the State government was pr vided, section 1172–2 of the General Code providing for the appoin ment of a board of control of five members was repealed, and t board of trustees of the Ohio State University and the State direct of agriculture were constituted the board of control of the exper ment station. The legislature also passed three bills relating forestry, providing for a State forester and fire wardens and for t

prevention and suppression of forest fires, and making the chief of the department of forestry of the Ohio experiment station ex-officio State forester; providing for the establishment of a State forest nursery and enabling the creation of municipal, township, or county forests, and the levy of taxes therefor. Action taken by the board of control in January, 1919, uniting the departments of animal husbandry and nutrition in a new department of animal industry, which had been contested, went into effect in the spring of 1921, as a result of the courts in favor of the station administration.

The adoption of the administrative code by the Washington Legislature, consolidating the numerous boards, commissions, and offices of the State government into 10 executive departments, responsible to the governor, removed from the State college and experiment station the office of farm markets and discontinued the State board of agriculture, of which the director of the station was an ex-officio member.

CHANGES IN PERSONNEL.

At no time in the history of the experiment stations have changes come so rapidly in their administrative officers as in the past few years. From 1914 to 1920 the directorship of practically half the experiment stations changed. During 1921 ten more changes were added to the list, affecting the stations in Alabama, Florida, Maine, Minnesota, New York, Ohio, Oklahoma, Utah, West Virginia, and the Virgin Islands. The list was further extended by the death in the fall of 1921 of H. P. Armsby, director of the Institute of Animal Nutrition at the Pennsylvania State College.

This is an almost unprecedentedly long list for a single year and includes a number of directors who are conspicuous for the length and the character of their service. Four of these men had been associated with the experiment stations since their organization under the Hatch Act 34 years ago, and three were almost the last connecting links between the original State stations and the national system which grew out of them. Two others had been in the station work nearly or quite 30 years, while two more had served the stations for 14 and 17 years, respectively.

Whitman H. Jordan.—Doctor Jordan, who in June, 1921, retired from the directorship of the New York State station, which he had held since 1896, was one of the pioneers who aided in founding and building the American system of agricultural research. He was the first director of the Maine Fertilizer Control and Agricultural Experiment Station, established in March, 1885, and was called to the position from the professorship of agricultural chemistry in the Pennsylvania State College, where he had instituted a series of plat experiments. Doctor Jordan for many years was a great force in the upbuilding of the ideals and purposes of the American stations. From the first he exhibited a clear vision of the field and function of the experiment station as an institution for acquiring information through experiment and research. He was an active worker in the Association of American Agricultural Colleges and Experiment Stations and on many occasions set forth his high ideals for the stations, defining the essentials of research, pointing out tendencies he believed to be injurious, and presenting constructive suggestions.

His clear analysis of problems and the requirements for their solution was most helpful. He has a worthy successor at the station in Dr. R. W. Thatcher, formerly dean and director of the agricultural college and experiment station in Minnesota.

Charles E. Thorne.—Professor Thorne, who was relieved during the year of the directorship of the Ohio station at his urgent request had served continuously in that capacity for 33 years. He had been associated with the movement for securing Federal support for an American system of stations, and had preserved the historical records of the successive attempts. Prior to the passage of the Hatch Ac the Ohio station had received from the State about $5,000 annually Under Professor Thorne's directorship the appropriation grew to ap proximately $300,000 a year, the largest for any of the stations. Thi remarkable growth is a product of the constructive planning an leadership of its director, supported by a confident and appreciativ commonwealth.

Despite the heavy burden of administrative responsibility Profes sor Thorne had for years been actively associated with the station' investigation in the field of soil fertility, and he had for severa years sought relief in retirement from the directorship in order tha he might devote himself wholly to digesting and summarizing th results of this work. He is succeeded by C. G. Williams, agronomis of the station and for several years vice director.

Henry P. Armsby.—Doctor Armsby, director of the Pennsylvani Institute of Animal Nutrition, who died October 19, 1921, was th foremost exponent of research in the field of animal nutrition in th country and an international authority. For more than 40 years h had been closely identified with the work of the agricultural institu tions. He entered the service of the Connecticut State station i 1877, two years after its establishment, and, except for an interval o two years in which he was vice president of the Storrs Agricultur School (now the Connecticut Agricultural College), he was continu ally in the service of the experiment stations up to the time of h death.

With the organization of the experiment station in Wisconsin 1883 he became its chemist, and with the passage of the Hatch A he was called to Pennsylvania to organize the experiment station that State. He remained director of the station until 1907, when his request he was relieved of the larger administrative duties of t station, and with the establishment of the Institute of Animal Nutr tion, a product of his vision in that field, was enabled to concentra his attention on this special line of inquiry.

Doctor Armsby was a wise and inspiring leader in the field research, a faithful interpreter of the method and the results science, and a man of very broad influence in the development of t purposes and the standards of the American experiment station.

Administrative and other changes.—Among others who reli quished directorships during the year, three deserve especially to mentioned because of the long period of their service, namel Charles D. Woods, for 25 years director of the Maine experime station and previously chemist and vice director of the Connect Storrs Station from its organization in 1877; J. F. Duggar, wh service began as assistant director at the South Carolina station

1890, and who was for 18 years director of the Alabama station; and P. H. Rolfs, who, with two short interruptions, has been associated with the station work since 1891, and director of the Florida station for 15 years. These men were conspicuous in their respective fields, and the stations over which they presided owe much to them for wise development and administration. They were succeeded by Dan T. Gray as director of the Alabama station, Wilmon Newell at the Florida station, and W. J. Morse at the Maine station.

H. G. Knight, who withdrew as director of the Oklahoma station, was succeeded by C. T. Dowell. F. S. Harris, director of the Utah station, left to accept the larger administrative position of the presidency of Brigham Young University, being succeeded by William Peterson. J. L. Coulter, dean and director in West Virginia since 1915, left to become president of the agricultural college in North Dakota. W. C. Coffey, of the Illinois college and station, succeeded R. W. Thatcher as dean and director at the Minnesota college and station July 1, 1921.

In this connection mention should be made of the passing of C. H. Fernald, a pioneer in the field of economic entomology, and associated with the work in Maine and Massachusetts from 1871 until his retirement in 1910. Doctor Fernald was for many years entomologist at the Massachusetts experiment station, and as a teacher trained an unusual number of men who have attained eminence in economic entomology. He died February 22, 1921, at the age of 83 years.

In addition to these administrative changes there was a long list of resignations or changes in the heads of important departments of the stations.

Resignations at the Alabama station included A. F. Thiel, head of the plant pathology department; J. C. Price, associate horticulturist; and G. S. Templeton, head of the animal husbandry department, the latter being succeeded by J. C. Grimes.

At the California station resignations included J. E. Coit in citriculture and D. T. Mason in forestry; and appointments included R. F. Miller, professor of animal husbandry; C. A. Phillips, associate in dairy husbandry; B. A. Rudolph, research associate in plant pathology; and W. E. Tomson, associate in animal husbandry. S. Lockett was appointed associate in veterinary medicine and resigned during the year.

At the Delaware station J. M. LeCato, associate plant pathologist, resigned and was succeeded by J. F. Adams. Changes at the Florida station included the appointment of O. F. Burger in charge of the plant pathology department, succeeding H. E. Stevens and C. D. Sherbakoff. R. P. Bledsoe was appointed agronomist at the Georgia station, to succeed T. S. Buie, resigned. At the Idaho station G. R. McDole was appointed associate agronomist, giving primary attention to soils, and H. P. Davis, head of the dairy department, resigned to accept a similar position at Nebraska College and station. In Indiana O. G. Lloyd was appointed chief of the department of farm management; H. W. Gregory, chief of the department of dairy husbandry, succeeding O. E. Reed, who resigned; J. J. Davis became chief of the new entomology department; and T. M. Bushnell was made associate in soil survey.

The changes at the Iowa station involved mainly assistants, but included also the resignation of H. B. Munger as chief of the farm management section, and the appointment of C. L. Holmes as assistant chief of the agricultural economics and farm management section, and of F. F. Sherwood as assistant chief of the dairy section. At the Kansas station L. F. Payne was appointed associate in poultry husbandry; B. M. Anderson, assistant, succeeded E. F. Ferrin as associate in animal husbandry; R. J. Barnett was appointed pomologist; and R. M. Green succeeded F. L. Thomsen as associate in agricultural economics.

The more important changes at the Louisiana station included the appointment of J. F. Brewster as research chemist and the return of W. L. Owen as bacteriologist at the sugar station at New Orleans. T. H. Jones was appointed entomologist to the station, and G. Dikmans, as assistant in veterinary medicine, in charge of the department of parasitology.

In addition to the change in directorship at the Maine station, noted above, J. W. Gowen was appointed biologist to succeed Raymond Pearl. At the Massachusetts station G. H. Chapman, research professor in botany, resigned to accept a position in the tobacco work under the Connecticut State station. The only change of importance reported from the Michigan station was the appointment of O. E. Reed as head of the dairy department. W. H. Peters was appointed acting animal husbandman at the Minnesota station, to fill the vacancy caused by the resignation of C. W. Gay, who became head of the department of animal husbandry at Ohio State University.

D. J. Griswold resigned as animal husbandman of the Mississippi station and was succeeded by C. J. Goodell. Other additions to the staff included E. Brintnall, dairy department; J. C. C. Price, horticultural department; D. C. Neal, plant pathology department; J. N. Lipscomb, farm management; and E. P. Clayton, poultry department. R. R. Hudelson was appointed associate in soils at the Missouri station and resigned during the year. J. C. Wooley was appointed head of the agricultural engineering department; and R. M. Green resigned as associate in farm management. At the Montana station, the agronomist, P. V. Cardon, resigned, being succeeded by Clyde McKee.

Changes at the Nebraska station included the resignation of J. H. Gain, associate in animal diseases; J. H. Frandsen, head of the dairy department; and J. W. Calvin, associate in agricultural chemistry. H. P. Davis was appointed head of the dairy department and J. C. Russel, formerly assistant in agronomy, was made associate in soils.

There were an unusual number of changes at the New Mexico station. J. G. Griffith, head of the biology department, resigned and was succeeded by R. Middlebrook; R. L. Stewart, station agronomist, resigned, and C. A. Thompson succeeded him as acting agronomist, but resigned during the year; G. R. Quesenberry was transferred from the department of farm management to fill the position of agronomist; R. B. Thompson, head of the poultry department, was succeeded by F. E. Uhl; and the resignation of V. F. Payne, nutrition chemist, was met by the appointment of L. S. Brown.

Changes at the New York Cornell station included the appointment of D. B. Carrick in the pomology department, and the resignations of E. G. Montgomery, head of the department of farm crops, K. C.

Livermore, of the farm management department, and E. O. Fippen in soil technology.

At the North Carolina station F. E. Miller succeeded R. W. Collett as assistant director of branch stations; B. F. Brown was appointed chief of the division of markets, succeeding W. R. Camp, resigned; D. T. Gray, head of the animal husbandry department, resigned to accept the directorship of the Alabama station; W. A. Withers, who had been chemist at the station for many years, was assigned wholly to college duties; and H. M. Lynde, drainage engineer, died during the year.

At the North Dakota station R. F. Beard, cereal chemist, resigned and was succeeded by C. E. Mangels. C. D. Grinnells resigned from the animal husbandry department and was succeeded by J. W. Haw, who later in the year resigned and was succeeded by D. J. Griswold. A new department of entomology was added to the station and R. L. Webster appointed as its head.

At the Ohio station, following the resignation of the director, C. E. Thorne, C. G. Williams served as acting director during the remainder of the year, being later appointed director. Professor Thorne continues his connection with the station as chief of the department of soil fertility. W. J. Green resigned as chief of the department of horticulture and was appointed consulting horticulturist. J. H. Gourley was appointed chief of the department. E. B. Forbes, chief of the animal-industry department, resigned, being later succeeded by Gustav Bohstedt, and D. C. Kennard was appointed associate in the department.

Among the changes at the Oregon station is noted the appointment of R. C. Jones as associate dairy husbandman and a few changes among the assistants.

At the Rhode Island station H. G. May was appointed to succeed P. B. Hadley as chief in animal breeding and pathology and P. S. Burgess was appointed associate in agricultural chemistry.

At the South Dakota station A. T. Evans succeeded M. Champlin as associate in agronomy.

The changes in the staff at the Tennessee station included the appointment of C. D. Sherbakoff, of the Florida station, as pathologist, and S. Marcovitch as entomologist to succeed G. M. Bentley.

The Utah station lost by death G. B. Hendricks, in charge of the marketing work, and W. L. Wanlass was appointed to fill the position. W. W. Henderson resigned as entomologist. G. A. Olson resigned as head of the division of chemistry in the Washington station, and was succeeded as acting head by J. L. St. John.

Appointments at the West Virginia station included E. P. Deatrick as associate soil technologist, R. J. Garber associate agronomist, and J. H. Gourley as horticulturist to succeed J. K. Shaw, resigned. L. M. Salter resigned as head of agronomy and soils. At the Wyoming station E. H. Lehnert resigned as head of the veterinary department and Cecil Elder was appointed acting head. F. A. Hays was appointed associate animal husbandman.

These changes in personnel were in part due to personal preference and advantage, and in part to an upbuilding and strengthening of the station staffs. In a number of instances specialists who went out into commercial positions returned to continue their sta-

tion activities. Salaries were made somewhat more attractive, and the relation and position of the station and its staff within the institution were more definitely recognized. Conditions as a whole became more stable despite the many changes, and the opportunities offered for a career in the stations presented a more encouraging outlook.

ADDITIONS TO BUILDINGS AND EQUIPMENT.

Changes in the physical plant have been on a rather limited scale, owing to the paucity of funds and to high prices. In a number of cases the stations have shared or are to share in new buildings erected for the general use of the colleges, and in others the acquisition of land by the colleges has added to the facilities for experimentation.

In a number of instances the need for expansion is becoming quite urgent. At several of the stations the question of securing farm land adjacent or convenient to the station is becoming a serious one, owing to the growth of the communities in which they are located. Outlying farms located at a considerable distance have been acquired to some extent, but these have the disadvantages of being time-consuming to visit and not having the close oversight which experimental work usually requires.

The agricultural building of the Alabama Polytechnic Institute which housed a large part of the station activities, was unfortunately destroyed by fire during the year. A considerable portion of the equipment of the departments of administration, agronomy, soils plant pathology, botany, entomology, horticulture, and animal husbandry was lost. The loss of the records in these departments seriously interrupted the work of the station, involving the field notes and data secured through many years, which can not be replaced. This emphasizes the necessity of keeping such records in fireproof vaults, and also the advantage of duplicate records.

At the Arizona station a dwelling for the foreman at the Salt River Valley Farm was completed. On the university campus a new milking barn was completed during the year, and also a greenhouse with 1,500 square feet under glass. A seed-testing apparatus valued at $600 was secured.

The California Legislature provided $400,500 for buildings and improvements at the university farm at Davis. These will be erected during the coming biennium, the two principal buildings to be one for the activities of the dairy department, including a plant for the manufacture of butter and ice cream and the pasteurization and distribution of market milk, and a building to house the division of pomology, viticulture, and botany.

At the Connecticut State station a field of 13½ acres of tobacco land was purchased with the Lockwood trust fund for experimental work on tobacco.

The creamery at the Georgia station was enlarged and supplied with equipment including separators, churns, and aerators.

The Illinois Legislature appropriated $500,000 for the first unit of a new agricultural group. This will be devoted almost exclusively to instructional purposes, but it is the beginning of a new plant which will serve the experiment station as well as the college. The legi

lature also appropriated $260,000 for a horticultural field laboratory, which is nearing completion.

At the Indiana station a new horse and cattle barn and a poultry house were constructed at the Moses Fell Annex at Bedford. An extension was added to the dairy barn at the university, accommodating 20 cows.

The Iowa station reports the purchase of a farm of 176.6 acres for the animal husbandry section. This adjoins the college lands on the Lincoln Highway. An experimental sunlit community hog house will be built, and a complete cattle and sheep experimental barn with paddocks is being planned to meet the future developments of the animal husbandry experiments.

In Mississippi a residence was built at the Delta substation for the assistant director, costing $10,000, at the Holly Springs and South Mississippi branch stations potato-curing houses were added, and at the new substation at Raymond a dwelling, barn, and minor buildings were erected.

The remodeling of the horticultural and botany buildings at the Minnesota college, at a cost of $90,000, afforded additional laboratory facilities for station work in horticulture and plant physiology and pathology.

In Missouri the State appropriated $150,000 for a new agricultural building, which will provide offices and research laboratories for investigation. The department of soils and rural life, the agricultural library, and the dean's office will be located in this building. A new cattle barn was also provided for, to cost $18,750.

Additions to the equipment of the Nebraska station included the installation of thermographs and temperature boxes for the study of bacterial diseases, and equipment for the agricultural engineering buildings.

The Nevada station reports the addition of a sheep shed with equipment including feeding racks, watering troughs, etc., for lambing and feeding tests. One and a half miles of dog proof woven and barbed wire fence was built on the station farm.

Work was begun on a new building for the department of dairy industry at Cornell University, and the contract was let for a new agricultural building in North Dakota. A beef-cattle barn was constructed at the coast station, South Carolina, at a cost of about $2,000.

The University of Tennessee completed and dedicated an imposing agricultural building, located at the university farm and adjacent to the extensive field work of the experiment station. A large part of the building, especially its laboratories, was specially designed for the use of the experiment station and with respect to its needs. The station headquarters, library, and major departments are brought together in this building.

At the Utah station a new plant industry building was completed, costing about $150,000. An irrigation laboratory was installed in the agricultural engineering building, to cost about $1,200, in which the station has a half interest. A tract of 17 acres adjoining the Greenville farm was purchased for $7,125, and a horticultural farm of 20 acres along the interurban railway between Ogden and Salt Lake City was secured. Permanent equipment to the value of $5,400 was added to the station.

Additions to the West Virginia University and station included a new barn at the horticultural farm, costing $10,000, and two large egg-laying houses, costing $1,800 each, and a new brooder house, costing $1,000, at the poultry farm. The old dairy barn was repaired at a cost of $2,800. On the animal-husbandry farm a completely equipped hog barn was constructed, costing, with new equipment, $5,500. On the agronomy farm, $7,500 was expended for concrete foundations, a new pumping system, and repairs.

STATION PUBLICATIONS.

There was a revival of activity during the year in the publication of results of experiment station work. For several years the publications had been lagging behind because of the cost of printing and the condition of the station funds. Many technical papers were prepared for publication in scientific journals, as has been the practice of late. These dealt with aspects of investigation which were of special interest to students of the subject, the practical results and their application being issued in the station series. Of late there has been much attention to the systematizing of these outside publications, sometimes bringing them into a regularly numbered series and otherwise arranging for the securing of separates to make up library sets and for exchange purposes.

There has been a decline in the voluminous annual reports formerly issued, and instead a brief administrative report with a record of progress on the projects and the chief events of the year has become common. Several stations have given special effort to preparing a report in popular form, summarizing for the public the chief results attained and giving reports on the progress of other projects, together with matter of general interest. These reports have had the effect of popularizing the station work and bringing it home to the general reader. In addition, more attention has been given to press reports of the station activities and results, employing in some cases the avenues of publicity opened up by the agricultural extension work. These efforts have been well worth while, for the public deserves to be kept informed promptly on matters of interest, and, on the other hand, the station deserves to have its hearing before the people. So much of the work is now of a technical character, owing to the nature of the problems presented for study, that it needs to be explained and interpreted in order that its practical bearings may be understood and appreciated.

A bibliographic help which is worthy of special note was prepared by Miss M. Helen Keith, of the Illinois station, and issued by the National Research Council, under the title "Bibliography of Investigations Bearing on the Composition and Nutritive Value of Corn and Corn Products." It occupies nearly 200 manuscript pages and contains over 1,200 separate entries. It is designed primarily to aid investigators and research students in the nutritional side of the corn-feeding question.

An attempt is made for the first time to classify in this report the principal station publications of the year. Omitting press bulletins and others of more transient nature, the list includes 75 annual or biennial reports of the stations, substations, and other

features, 23 periodical bulletins, and 51 bulletins relating to inspection or regulatory work. Of the regular bulletins, 52 related to soils and fertilizers, 76 to field crops of various kinds, and 52 to horticultural subjects.

There were 46 bulletins dealing with diseases of plants, 46 with entomology, and 17 with veterinary medicine, while 66 were devoted to animal production and 37 to dairying and dairy farming. Agricultural engineering had 15 bulletins, and rural economics, a relatively new subject, had 41. In addition there were quite a number of bulletins under such general heads as agricultural chemistry, botany, meteorology, human nutrition, and miscellaneous.

The classified list of these publications is given at the conclusion of this report (p. 118).

SOME RESULTS OF STATION WORK.

Following is a condensed summary of the more outstanding results of the work of the stations for the year. Conditions have been quite favorable for investigational work, and good progress has been made in many important lines of study. While many of the problems are of such a nature that they may extend over a series of years, others are of shorter duration, giving results perhaps in a single season. Some of the more fundamental problems in agriculture engage the attention of most of the stations, others having more local application.

BOTANY AND PLANT PHYSIOLOGY.

Plant nutrition.

Experiments at the Indiana station show that aluminum and ferrous iron ions are very injurious to plant growth, and that it is necessary to maintain conditions in the soil which will keep them unavailable to the plant. Their effect on the plant is the production of streaking and intervascular tissue necrosis of the leaves, and a discoloration and disintegration of the vascular plate tissues in the nodes of the stalk. This can be corrected by adding soluble phosphates to the soil. At the New Mexico station it was found that iron may be present in sufficient quantities in the soil surrounding plants affected with chlorosis, but its utilization may be hindered by some other soil constituent.

The New Jersey station reports that a slow current of air passed through media, either solution or sand cultures, almost doubled the yields of crop as compared with those obtained from untreated cultures. Cultures for soy beans, which produced high yields of either tops or roots, were characterized by high percentages of calcium nitrate and were correspondingly low in magnesium sulphate, these two compounds apparently being the determining factors in the yield, monopotassium phosphate having less influence. The highest yields were obtained from sand cultures in which the solutions were continually renewed by a constant drip of the nutrient solution, thus affording aeration. The quantity and form of air needed for maximum plant production in nutrient media are determined by a number of different factors, including the H-ion concentration, concentration of soluble phosphates, and other salts forming precipitates with iron, volume of the medium employed, the number of plants

in a given volume of medium, and the nature of the light, more iron being required during periods of sunshine and less during cloudy periods. Chlorotic conditions and low yields resulted from cultures in which ferric phosphate was the only source of iron, this being correlated with high Ph values. This form of iron, however, was readily available in solutions containing ammonium sulphate, and in such, high yields were associated with relatively low Ph values.

The California station finds that temperature is a very important factor affecting the growth efficiency of nutrient solutions. Those high in phosphorus or magnesium were not as good culture media for wheat seedlings at relatively high temperatures as at relatively low ones. Solutions high in calcium nitrate showed a better growth efficiency at high than at low temperatures. Wheat grown in water cultures showed a direct stimulation of growth when the concentration of sodium chlorid was about 5,000 parts per million, but when this reached 14,500 parts per million the plants died. There was no effect at very low concentrations. Small amounts of manure added to pots containing sodium chlorid, carbonate, and acid carbonate, had a marked preventive action on the toxicity of these salts to growing barley.

The Montana station finds that arsenic in the soil disturbs the normal function of plants, but its effects soon disappear, due largely it is thought, to the development of tolerance.

Studies at the Delaware station show that toxic effects and permeability may be altered by the use of compounds giving identical ions but in a changing ratio of anion to cation in different mixtures. The specific effects of any given salt do not seem to depend wholly upon the fact that the metallic (positive) element of the compound is monovalent or divalent, or that it may be an alkaline earth or an alkali metal, but is the resultant of the individual effects of each ion itself upon permeability.

The New Jersey station finds that nitrogen in the stems of plants is directly related to fruit production, a low nitrogen content of the stem being always correlated with high fruit production, and vice versa. This correlation was not shown in the leaves or roots, indicating that the nitrogen translocated to the developing fruits is largely drawn from the main stems of the plants.

It is noted at the Kentucky station that in the utilization of the reserve material in the cotyledons, in the growth of beans, a smaller proportion of calcium than of phosphorus or magnesium is translocated.

At the Delaware station indications are found that the several enzymatic processes do not keep step with the increase of the vegetative activity of the plant, but that the enzymatic response to the addition of the compounds used as fertilizers is markedly specific and affects the various enzymatic activities differently. These processes have been utilized to form a new basis for the selection and breeding of corn, by which means it was possible to produce highly inbred strains that equalled cross-bred corn in vigor.

Isolated cornroot tips were successfully grown in sterile nutrient solutions, at the Missouri station, if glucose was present. In Pfeffer's solution, containing 2 per cent of glucose, cornroot tips made a lim-

ited growth in the dark, which was increased in the light. The addition of peptone or autolyzed yeast improved the growth. In a mineral nutrient solution containing glucose, mineral salts, and autolyzed yeast, isolated cornroots were maintained for more than 12 weeks in the light.

Studies on sap concentration at the California station show that the sap is most diluted when new shoots are just beginning to form and most concentrated when they are in a dormant condition. Pruning tends to reduce the concentration.

Moisture relations of plants.

Studies in transpiration, mainly with corn, at the Nebraska station, showed that this varied, per gram of dry matter, from 192 to 445 grams in two extreme years. The results show that transpiration is directly dependent on weather and leaf area, and is proportional to evaporation from a free-water surface. High evaporation and transpiration are reflected in low yields. The transpiring leaf is somewhat cooler than the atmosphere in the hottest part of the day, but a dry leaf without water to transpire becomes hotter than the air. Little encouragement was found for the selection of strains on the basis of low transpiration, but more for selection on a basis of dry matter. A wide difference was found between plants and varieties in water requirement, smaller varieties and those with smaller leaves taking less water, although the proportion to dry matter was practically the same. Some crops, like sunflowers, are extravagant users of water as compared with corn.

The Nebraska station finds that the adaptation of corn to regions of low rainfall consists chiefly in the reduction of vegetable development and consequent reduction in the amount of water used by the individual plant, and this factor rather than lower transpiration per unit of dry matter produced accounts for the variation in water requirements of different varieties. The amount of water used per pound of dry matter varies very little regardless of the native source or acclimatization of the seed. The use and economy of water differ greatly in different years, following roughly the evaporation from a free-water surface during the principal growing period of the plants. Comparing results from fertile and infertile soils, the latter produces smaller plants which use less water per plant but not more per pound of dry matter. An increase in soil fertility reduces the transpiration (dry matter ratio) until the optimum fertility for plant growth is reached. The remedy for lack of water is not found to be an increase in soil fertility.

The Minnesota station found that awns on wheat are very important from the standpoint of transpiration, this being twice as great where awns are present as where they are absent. This may have some correlation with the larger grains of awned wheat.

Effects of light.

Investigations at the New Hampshire station show that the intensity of sunlight or the amount of solar radiation received by plants has a marked effect on type of growth and size, structure, and color of their leaves, their roots, and upon their reproductive processes as indicated by flowering. The leaf area was increased by shading, sometimes as much as 200 per cent. The thickness of the

leaves was greatly reduced in some cases, in the apple nearly 100 per cent, the modification involving particularly the palisade cells and mesophyll. Moderate shading intensified the green color of the foliage, and the leaves dropped several days earlier than the checks. The root systems were materially reduced by growth in the shade. In herbaceous plants, flowering was reduced and sometimes entirely suppressed, and it was reduced and delayed in fruit trees.

At the Massachusetts station oats were grown under different amounts of light. When grown from seed from plants in which the intensity had been reduced about 30 per cent, a more vigorous germination and a stronger plant resulted. Plants exposed to ultra-violet light from the mercury vapor lamp, in addition to daylight, gave considerably more vigorous growth, which, however, was more brittle. By screening out all ultra-violet rays there was a more vigorous growth of seedlings, up to a certain point only. In the radish where the rays were not sifted out the roots have a red color, but where these rays were eliminated the roots were white. In general, the long ultra-violet rays were found to be injurious, coagulating the albumin and injuring the cells rapidly.

Seed studies.

Seed studies at the New Jersey station show that differences in weights have a very pronounced influence upon germination, subsequent development of the plants, time of flowering, production of fruit, and time of fruit maturity. A marked difference was found in the absorption of water by the seeds of different species. Legume seeds showed a higher rate of absorption than others. Among those treated, alfalfa showed the highest and corn the lowest. The absorption rates decreased with increase in the osmotic concentration, except in dilute solutions.

A quick method of determining the germinating ability of seed requiring only a few minutes, based on the peroxidase reaction with guaiacum, has been devised by the Kentucky station.

Effect of manganese.

The results of an investigation at the Kentucky station show that when manganese is added to an acid soil toxicity is developed. Using radishes as a crop, while the tops did not show much effect, the roots were much diminished by the presence of manganese in an acid soil and where the manganese reached 50 parts per million in the soil extract the plants would not grow. In a neutral soil the growth was better and toxicity did not show until 100 parts per million was reached. Peas grown in water cultures with no manganese began to deteriorate after a normal growth for four or five weeks, the young buds dying back. The seeds contained a small amount of manganese to begin with, which was evidently sufficient for the first stages of growth. Plants receiving manganese made a normal growth. Carried to blooming, they gave a higher dry weight. Plants receiving a solution of 8 to 10 parts of manganese per million began to show toxic effects, but up to 4 to 6 parts they made a normal growth. Soy beans, cowpeas, and corn were grown with similar results, those receiving traces of manganese giving markedly higher green and dry weights. The results show that from 0.1 to 1 per cent of manganese in the soil is beneficial, but more than this causes diminution of the crops. Legumes seem to require this element more than nonlegumes

The Alabama station finds that sorghum will stand considerably more manganese than clover.

Effect of soil temperature.

At the Wisconsin station a difference is found in the composition of wheat grown at different soil temperatures, the carbohydrates in the stem and leaves being higher when grown at lower temperatures. With corn, the results were not as conclusive, but there was more hemicellulose at higher soil temperatures. Corn was also found to be more resistant to root rot organisms at higher temperatures, differing from wheat in this respect.

GENETICS.

Determination of characters.

Data secured at the New York Cornell station show that there are one or more modifying factors concerned in the development of the red color of cabbage.

The Oklahoma station in working with sheep find indications that early lambing is an individual and not a racial trait. The absence of horns is found to be dominant to their presence.

Studies at the Connecticut Storrs station show that the difference between high, mediocre, and low producing hens depends on two dominant factors, one sex-linked, and the other autosomal. Absence of both determines low fecundity, the presence of either, mediocre, and the presence of both, high fecundity.

At the Massachusetts station broodiness is found not to be a single Mendelian dominant. The male is a large factor in its transmission. There are evidently two factors involved in broodiness.

At the Wisconsin station the various stages of "blueing," the replacing of black by blue in the plumage of pigeons, appear to depend on separate, definite, independently heritable factors, whose expression is such that each one higher in the series (producing more black) covers the effect of all those below.

At the Kansas station 10 characters have been located in studies on the grouse locust (*Apotettix eurycephalus*) with such definiteness that a chromosome map may be made. Twelve forms with three different combinations have been produced in which individuals breed true. Twenty or more generations have been secured with a very distinct mutant of Paratettix.

Correlation of characters.

A study of the correlation of characters in corn at the Virgina station showed that the later the plant flowered the lower the yield. The correlation between the yield and length and width of leaf is low, but there is 63 per cent correlation with the size of stalk and 75 per cent with the weight of stalk. The correlation of ear characters and weight of grain was high, except with that of tapering ear, in which it was only 50 per cent.

Cotton studies at the Texas station indicate a correlation of oil content with lint characters and protein, but not with total yield.

Work with oats at the Alabama station showed a close correlation between height of plant and yield, the latter being heavier with the taller plants.

Resistance to stem rust in oats is found at the Minnesota station to be a simple Mendelian dominant and easy to transmit to the third generation.

A study of the correlation of characters in the peanut, at the Alabama station, showed this to be low in the percentage of meats to the weight, also in length of stem to percentage and weight of nuts and meats. A high correlation was found between the number of branches and weight of meat, and the weight of meat to the weight of nuts in the shell. No correlation was found between the length of stem and total weight of vegetative parts or the percentage of meats to the number of single pod nuts.

Linkage of characters.

Studies at the New York Cornell station on the relative intensity of linkage in pollen and ovule development indicate that there is little difference in the frequency of crossing over in mega- and microsporogenesis in maize. It was also found that the intensity of the linkage of factors, in at least one linkage group in corn-teosinte hybrids, is markedly different from that in pure corn, while in others the strength of linkage is practically the same as in pure corn.

At the South Carolina station barrenness in corn is found to be a hereditary factor linked with purple color. The stalks of barren corn are larger and the plants heavier and stockier. A rather high percentage of barrenness is found in common corn, from 5 to 12 per cent in most fields, this being on the female side only, normal tassels being produced. It can be reduced by detasselling the barren stalks before the tassels develop.

The study of inheritance of spangling in poultry at the Missouri station shows this to be controlled by a sex-linked factor. Hen feathering in the males of the Seabright bantams is transmitted through both sexes by a single dominant factor, which is not sex-linked. A cytological study of the testes of male and female feathered cocks gave no evidence that male feathering is due to an internal secretion from the so-called lutear cells of the testes.

Crossing.

A method of inbreeding corn has been devised by the Connecticut State station that is being extensively used. It involves the bringing together each year of inbred strains, the progeny of each pair being the parents of the improved strain. Four stock inbred strains must be carried and the crossing repeated each year. It is giving excellent results.

Strains of cotton selfed for nine years at the North Carolina station show no lack of vigor, and the F_1 hybrids do not show exceptional vigor, which is contrary to what has been observed in case of corn. The natural crossing of cotton is found to be 4 to 6 per cent only. As this plant has 52 to 54 chromosomes, there is a chance to combine several characters. Strains have been obtained that for [illegible] years have varied in averages from 985 to 2,061 pounds per acre of seed cotton and from three-fourths to $1\frac{1}{8}$ inch staple.

In work with wheat at the New York Cornell station it was found that, while neither Polonicum nor Kubanka are pubescent, the F_1 plants are pubescent and in the F_2 hybrids various types of pubescent forms are obtained. On the long-glumed types no pubescence is found.

The Maine station has shown that milk yield and butter fat per-
entage are definitely transmitted by both sire and dam to the first generation crosses of dairy and beef breeds. High milk production s partially dominant to low and low butter fat percentage to high.

SOILS.

oil fertility.

Studies in soil fertility at the North Carolina station showed that Norfolk fine sandy loam is decidedly more responsive to fertilizers han Cecil sandy loam or Toxaway loam. Corn was a more efficient rop than wheat on both the latter types of soils. A closer relaion was found between chemical analysis and field experiments vith reference to plant food deficiencies in the Piedmont region han in the Coastal Plains, potash being more important and phoshoric acid less so in the latter than chemical analysis indicates. In he black-land soils profitable crops can not be grown without the use f lime. Fertilizing without lime depressed the yield, and the aplication of 3 tons of lime per acre did sweeten the soil to a depth f 8 inches. Contrary to the general belief and practice, the use of me was found to greatly increase the yield of tobacco, when grown n bright tobacco soil, without apparently affecting deleteriously the uality and selling price, and also contrary to the long accepted idea n this same soil the use of muriate of potash produced a greater ield of tobacco than sulphate of potash without apparently injuring e market quality.

At the Kentucky station on certain types of soil which were nearly eutral, rock phosphate gave as good results as acid phosphate. Exeriments at the Texas station showed a closer relationship between e active phosphoric acid of the soil and the results obtained with ot experiments than in the case of the total phosphoric acid. At the hio station the addition of basic material (lime) enabled more hosphoric acid to be taken up from an acid soil.

Results at the latter station showed the fixing capacity of soils for otash to be greater where they had not received this element than here it had been applied. Limed soils were found to have a greater pacity for fixing potash than unlimed.

At the Utah station wheat plowed under when 6 inches high, ? inches high, in early bloom, and in the milk stage, showed decided ductions in yield in a succeeding crop of wheat as the different ages advanced for plowing.

At the Rhode Island station, where corn was grown continuously ith a complete fertilizer containing 20 pounds of nitrogen per acre d with a legume cover crop plowed in, a yield of 84 bushels of corn s obtained. Sixty pounds of nitrogen with a rye cover crop gave bushels, and with no cover crop, 55 bushels.

il acidity and liming.

Extensive studies have been conducted on soil acidity and its cortion by liming. The Alabama station finds that applications of lphate of ammonia result in a pronounced increase in soil acidity.

A survey of the soils of the State by the Pennsylvania station owed that 72 per cent are in need of lime and that on only 15 per nt of unlimed soils can a good crop of clover be grown. The lime quirements of soils which had never been limed varied from 1,749 to

3,105 pounds per acre. Well-drained soils were found to be less acid than poorly-drained ones and the lime requirements were found to bear a close relationship to productivity.

Tests by the Oregon station showed that the red hill group of soils have the highest acidity, while the well-drained soils in the valley floor and recent stream and river bottoms had only slight or moderate acidity.

At the Rhode Island station the complete neutralization of all acidity by lime reduced the oat crop more than half. Chlorosis was noted in oats and other crops when the soil was completely neutralized, indicating that it is undesirable to lime so persistently that the soil will not impart a slightly pinkish color to blue litmus paper. A slight acidity seems to be favorable to the growth of plants. Data were secured which indicate that the effect of acid phosphate and lime in correcting acidity is probably due, in part at least, to precipitation of active aluminum by these substances. Similar results were observed at the Indiana station, which reports the acid phosphate instead of increasing acidity decreased it by precipitating the soluble aluminum salts. The Illinois station, however, finds no evidence that aluminum is a cause of acidity.

The Wisconsin station finds that corn is able to withstand more acidity than soy beans. Studies at the New Jersey station indicate that it is not profitable to try to grow the common legume crops, such as alfalfa, vetch, clover, soy beans, etc., on soils having a Ph value lower than about 6.5. In plats of different lawn grasses, at the Rhode Island station, soil acidity was maintained to such an extent by the application of sulphate of ammonia in place of nitrate of soda, that weeds were entirely eliminated.

The best soils, according to results obtained in pot experiments at the Kentucky station, have the highest total calcium content and vice versa. Cultivation results in the loss of calcium. Calcium treatment caused an increase of ash and calcium content in the plant regardless of any increase in growth.

The Tennessee station finds that heavy applications of lime remain largely as oxid or hydrate, changing only slowly to the carbonate. The effect of heavy applications on the mechanical condition of the soil is marked.

Experiments at the Iowa station show that gypsum has no effect on soil acidity, but seems to have some effect in making potassium available and stimulates certain bacterial activities. It does not, however, replace lime.

The Missouri station notes that the poorer soils give greater returns from the use of available phosphates than from lime, and it is believed that, with the present prices and freight rates, liming on such soils should only be done after the yields have been brought up as far as possible by the use of phosphates, barnyard manure, and rotations including legumes.

Indications from experiments at the New York State station are that both calcium and magnesium limestones, in amounts far below the calcium requirements of the soil, will produce normal yields, especially of alfalfa. In some cases small applications have given more satisfactory results than large ones.

An examination of 50 soils at the Iowa station showed no correlation between the lime requirements and the H-ion concentration.

sandy loam with a low lime requirement may have a much higher H-ion concentration than a silt loam with a much greater lime requirement. An acid soil low in organic matter showed a higher H-ion concentration than one of the same lime requirements having a high content of organic matter.

The Oklahoma station reports that after five years lime had penetrated through 2 feet of hardpan on Kirkland subsoil. Kafir and alfalfa roots had penetrated the hardpan from 2 to 2½ feet where lime or manure had been added, but not where these were omitted. At the Oregon station an increase of ammonification followed the application of up to 4 tons of lime per acre, and nitrification increased in proportion to the amount of lime added up to that limit. Lime promoted aeration and fixation of nitric acid and favored nitrogen fixation by Azotobacter.

The Rhode Island station reports that the residual effects of crops, which may be marked, appear to be dependent upon the reduction of bases (lime) and increase in acidity. The effects were much more uniform and less pronounced where the plats were limed.

In a liming test at the Alabama station corn and cotton were practically ruined, but no other crop was injured. The Tennessee station states that the occasional injury to crops by liming may be explained by the increased amount of nitrogen which the lime carries off, thus delaying maturity.

Soil alkalinity.

Experiments at the California station indicate that a small amount of barnyard manure has a marked preventive action on the toxic effects of relatively large quantities of soil alkalis. The resistance of wheat to sodium chlorid was found to be extremely high, and concentrations up to 6,000 parts per million showed distinct stimulation in growth, although a peculiar temporary depression occurred at the lower concentrations, which is effective both for roots and tops at certain stages of growth. Contrary to previous opinion, barley was found to be very tolerant of alkali. With calcium chlorid, sodium sulphate, and sodium chlorid in equal osmotic concentrations, calcium chlorid is the most toxic, sodium sulphate next, and sodium chlorid least. Where soils are not too alkaline, applications of sulphur were found to neutralize alkalinity.

A study by the station of the causes of the formation of alkali showed that it may be due, among others, to the leaching of granitic rocks, the interaction between chlorids and calcium carbonate, and the action of chlorids on silicates. When hydrolyzed and subjected to the carbon dioxid of the air these appear to form the black alkali. Larger amounts of gypsum than have usually been recommended are found to be necessary for the reclamation of alkali land.

The Massachusetts station reports that calcium sulphate depresses alkalinity, but not to the point of acidity, and that it also depresses the solubility of calcium carbonate. Muriate of potash, on the other hand, usually forms sodium chlorid in the soil, which has an opposite effect to that of calcium sulphate on alkalinity and the solubility of calcium carbonate. The Utah station finds the presence of organic matter to be an important factor in the toxicity of alkali. At the Arizona station, Sonora wheat was found to be much more resistant to black alkali than barley. The Oregon station concludes

that irrigation and drainage for removal of alkali by flooding, with open ditches 10 feet deep, followed by treatment with sulphur, gypsum, ammonium sulphate, manure, or straw will bring under cultivation much greasewood or sagebrush land in the State that is now practically worthless.

Soil bacteria.

Examination by the Kansas station of a large number of soils from that and other States showed that only about 12 per cent of those that had not been limed contained Azotobacter. These soils gave a reaction favorable to the growth of Azotobacter; that is, H-ion concentration of the solution of less than 1×10^{-6}. Some limed soils also contained none of these organisms. The minimum concentration for these was found to be about Ph_6. They were readily established in acid soils after neutralizing with calcium or magnesium carbonate and disappeared from limed soils as they became acid again.

Experiments at the New Jersey station indicate that growing plants have a beneficial influence upon oxidation activities in the substrata in which the plants grow and suggest a symbiotic relationship between the soil oxidizing organisms and growing green plants.

Studies at the Oregon station indicate that a little sulphur, especially in combination with lime, stimulates nitrification, maximum development of nitrates being obtained with the use of lime and sulphur. At the Colorado station, sulphur applied at the rate of 2,500 pounds per acre retarded both nitrogen fixation and nitrification. Straw decreases nitrification, as shown by results at the Illinois station, and results in loss of nitrogen.

Investigations by the Montana station showed that considerable nitrate was formed in alkali soils, especially those high in organic matter. An accumulation of nitrate was found in almost all kinds of rocks, due, it is believed, to oxidation of organic nitrogen. It is also found on the surface of old brick and mortar, cement, and building stones, supposedly due to fixation. The Colorado station has also made extensive studies on the occurrence of nitrates on the surface and inside of rock masses.

The Utah station has studied bacterial activity in dry land and in irrigated, manured, and unmanured soils, ranging from a loose sand to a very tight clay, and in soils devoid of and very rich in organic matter. Every soil gave a maximum ammonification when it contained 60 per cent of its water-holding capacity of moisture. Nitrification was at its maximum at about 65 per cent of moisture. Most of the soils showed two maxima for nitrogen fixation, one at 50 to 60 per cent and one at 70 to 80 per cent. The addition of alkalis to the soil changed the figures somewhat. The New York State station reports that Actinomycetes are more active under so-called toxic conditions than in normal soils.

At the Missouri station, soils that were well supplied with *Bacillus radicicola* were treated in various ways. Samples were left out of doors but protected from contamination. Others were dried in the sunlight and some in the dark, and later stored so as to be protected from contamination. After three years the sun-dried samples still had enough viable bacteria to produce good infection.

The Idaho station finds that accumulation of ammonia and nitrate is distinctly retarded by applications of sawdust, needles, cones, bark, and other tree products. The greatest retardation resulted from the application of cedar sawdust and needles, maple products being next in order of toxicity. The reduction of ammonia and nitrate accumulation ranged from 5 to 60 per cent. Nitrogen fixation was greatly decreased by some of the products and practically eliminated by others. These investigations indicate the cause of the low productivity of forest soils.

In a study, at the Alabama station, of soil toxins, of all the organisms isolated from 30 soil samples, 80 per cent were found to decompose vanillin and 20 out of 27 decomposed cinnamic acid. Salicylic aldehyde was found to be unavailable as a source of carbon to the organisms. A few were found that would decompose hydroquinone. Bacteria will not grow in caffein, but molds do.

Nitrification.

Studies at the Ohio station show that nitrification can not take place until some of the cells of the organism are broken down to give the initial energy to start the process. By the addition of hydrogen peroxid to ammonium sulphate the formation of nitrate is secured without the presence of organisms, supposedly by a change analogous to nitrification. The breaking down of cells appears to supply a product which corresponds in its action to the hydrogen peroxid in the chemical reaction.

At the Washington station it was found that straw applied to the soil stimulates reproduction of bacteria, but there is no disturbance in the balance of types present. The bacteria use the straw as a source of carbon and the nitrates in the soil as a source of nitrogen, transforming this into organic nitrogenous material unavailable for plant food. The more straw applied the greater is the loss of nitrates.

At the Washington station 12 to 15 per cent of moisture in the first foot was found to give the best conditions for nitrification.

Extensive studies on soil nitrogen at the Missouri station show that nitrate production is increased both in manured and unmanured soils by the addition of limestone. The rate of nitrate production on corn plats, both manured and unmanured, is low as compared with the timothy plats. The results of three years' study show that the growing crop is of much significance in the removal of nitrates, the accumulation being reciprocal to the rate of crop growth; that spring plowing increases nitrate accumulation, but a 3-inch surface tillage lessens the amount of nitrates in the upper 7 inches; and that a heavy straw mulch depresses nitrate production decidedly.

The New Jersey station reports that nitrates were found in considerable quantities in soil samples which showed the highest H-ion concentration, indicating that nitrification is not necessarily inhibited by a highly acid condition of the soil.

Nitrogen fixation.

The Kansas station finds that aeration is a determining factor in the development of Azotobacter. Protein synthesized by Azotobacter supplied with various sugars was found to act much like water-soluble B vitamin in case of animals, indicating that the organisms may be capable of producing this vitamin. The Ohio station found

Azotobacter capable of utilizing combined nitrogen and that only after this was exhausted did fixation of free nitrogen take place. The presence of Azotobacter, therefore, does not prove that free nitrogen fixation is taking place, as the organism will follow the line of least resistance. The California station reports that the fixation of nitrogen is proportional to the amount of energy consumed.

The Colorado station reports nitrogen fixation as taking place on sandstones, cultures being made from a number of samples from widely separated localities. A number of bacteria were found, but associated action apparently did not increase the activity of the nitrogen-fixing organism. It is believed that they derive their energy from rock-infesting lichens. Traces of nitrates were found in many rocks, lichens in these cases also evidently furnishing the energy required for the bacterial activity.

Five years' results of lysimeter experiments at the New York State station show an accumulation of from six to seven times as much nitrogen under alfalfa rotation as under timothy.

Loss of nitrogen.

Studies at the Tennessee station have demonstrated the accelerative tendencies of all forms of lime and magnesium, in small or moderate amounts, upon the outgo of nitrogen by leaching. They also show decided inhibition induced by excessive amounts of calcium and magnesium oxids and the recovery from the partial sterilization, as a parallel to reversion of the oxids to the carbonate forms. The initial tendency of the subsoil to stop the downward movement of nitrates is shown, together with the pronounced later tendency of the accumulation of the alkali-earth bases in the subsoil to cause either a yielding of the nitrates held there or else a generation of nitrates from the nitrogen stores contained in the subsoils.

The Texas station finds a close relationship between the nitrates produced in the soil and the amount taken up by plants in pot experiments, and that the amount of nitrates removed by the crop is reflected in a decrease of nitrates in the soil.

The New York Cornell station reports that the reduction of nitrates is especially active in soils under timothy and that bacterial activity is greater in cropped than in bare soils. Analysis of the drainage water from lysimeters at the New York State station, extending over five years with a Volusia soil, has shown that under a four-year rotation, including two years of alfalfa, the soil lost over seven times as much nitrate nitrogen as did the same soil under a rotation in which timothy replaced the alfalfa. In spite of this greater loss of nitrate from the soil under an alfalfa rotation, this soil has given in the barley crop succeeding alfalfa an increase of 4,370 pounds per acre over barley after timothy. The Kansas station finds it possible to maintain the soil nitrogen but not to increase it by growing alfalfa.

Effects of straw.

The Washington station shows that the nitrogen-carbon ratio in organic material returned to the soil has a very pronounced influence on the kind and rate of decomposition. Organic materials like straw having a wide nitrogen-carbon ratio (1 to 75) produce a depressing effect on the nitrate development, and this effect is felt until there

has been sufficient decomposition to cause this ratio to approach that of the organic matter in the soil (1 to 13). Before this stage of decomposition is reached nearly all of the carbon is lost as carbon dioxid, and consequently residues, like straw, can not be depended upon to materially influence the soil organic matter. When organic matter having a narrow nitrogen-carbon ratio (1 to 10), as in the case of legumes, is incorporated in the soil, there is an immediate and rapid nitrate development with little loss of carbon dioxid and indication of greater organic matter maintenance. The resulting high nitrate content, following the plowing in of a legume, frequently causes lodging or "burning" of the succeeding grain crop. When straw is spread on the legume before plowing in this difficulty is largely overcome. Nitrogenous fertilizer, when applied with straw, was effective in overcoming the decrease in yields of small grain, so commonly experienced when these are grown after straw has been applied alone.

Burning all the straw on the land at the Utah station gave yields of about 2 bushels of wheat less than where the straw was plowed under.

Soil sulphur.

From investigation at the Tennessee station as to whether the oxidation of soil sulphur was wholly chemical or partly due to bacterial action, it was found that sterilized soils still showed oxidation. Liming affects the outgo of sulphur as well as of nitrogen, the sulphur being lost as calcium and magnesium sulphate, none as sulphid. Considerable sulphur is brought down from the atmosphere, in some cases as much as 100 pounds per acre per year. Sulphur oxidation in the soil parallels nitrification. Most of the soil sulphur is in combination with calcium, some with magnesium, and a little with iron.

The New Jersey station has isolated two sulphur oxidizing organisms, one acting in an acid soil, the other in an alkaline soil.

Tillage.

In tillage tests at the Wisconsin station deep plowing and subsoiling were not found profitable, deep tilling tests giving the lowest yields. The Texas station also finds that the presence or absence of weed growth is of more importance than the exact nature of the soil mulch maintained by cultivation. In experimental plowings of 3, 6, 9, and 12 inches, 6 inches or less was the most economical. At the North Dakota station it was found that in dry years soils subjected to a great amount of cultivation do not appear to retain their moisture as effectively as land where less cultivation is practiced. At the Oregon station it is shown that summer tillage of fallow accumulates nitrates and conserves moisture.

Soil erosion.

Erosion experiments at the Missouri station showed that land plowed 4 inches deep in the spring and fallowed during the remainder of the year lost over 1 inch of the surface by erosion, land in corn lost 0.5 inch, and land in sod only 0.01 inch. Based on the amount of eroded material under the conditions of the experiment, 7 inches of surface soil would be eroded in 25 years on the plat that

was shallow-plowed and cultivated, in 50 years on continuous corn, and in 2,300 years in sod. The nitrogen loss was excessive in eroded soils.

Miscellaneous soil studies.

The West Virginia station reports that soil can be sterilized by pressure, but shows considerable variation due to water content, results being best when a fair amount is present. The H-ion concentration is not changed by this treatment. The method has been applied with success to potatoes for use as a medium on which to grow the late blight of tomatoes. Butter can be sterilized by this method, but its keeping qualities are injured somewhat.

In lysimeter work at the Tennessee station, shallow rims, 12 inches in height, were better than deep lysimeters for soil work, as the subsoil in deep tanks fixes the elements so that they do not appear in the drainage water.

The Utah station finds that a clear soil extract may be obtained by adding either lime, ferric sulphate, ferric alum, or sodium or potassium alum to the soil-water mixture and then filtering through a Chamberland-Pasteur filter or centrifuging. The last three give a clear solution with a minimum amount of salt. Lime, ferric sulphate, or ferric alum cause a considerable loss of nitrates. For the determination of chlorids and nitrates, five minutes is sufficient to agitate the soil with water, if the soil is finely divided, but a longer time is required if sulphates are to be determined, depending on the kind and amount present.

FERTILIZERS.

Phosphates.

Tests at the Illinois station show that if too great an excess of lime is applied with rock phosphate it has an adverse influence on the facility with which the phosphate becomes available. Large amounts of rock phosphate gave as good results at the South Carolina station as small amounts of acid phosphate. Good results were obtained with Tennessee blue rock.

In studies at the Georgia station of composting rock phosphates with organic ammoniates, a maximum availability of 3 per cent was obtained in six to eight weeks. Five months composting of cottonseed meal and rock phosphate resulted in a loss of 60 to 70 per cent of the total ammonia. Of the total dry matter in the compost mixture, the loss was from 25 to 35 per cent, but where a small amount of sulphate of ammonia was added only 8 per cent of the total dry matter disappeared, while 60 per cent of the total ammonia was lost. The amount of total phosphate made available varied from 7 to 20 per cent. When acid phosphate was applied with substances such as calcium carbonate or ferrous sulphate, which are capable of reverting it, higher yields were obtained in the second year than from applications of acid phosphate alone.

Studies have been carried on at the New Jersey station on the possibility of converting rock phosphates into an available form by means of sulphur oxidation.

At the Alabama station heavy applications of acid phosphate on very acid soils gave a phenomenal growth of sorghum, but there was

an entire failure of clover following this. Plats in wheat at the Missouri station gave increased yields of 6.2 bushels with calcined phosphate, 4.9 bushels with basic slag, 2.7 bushels with steamed bone meal, 2.3 bushels with acid phosphate, and 2.4 bushels with rock phosphate.

The Wisconsin station finds that sweet clover feeds strongly on raw rock phosphate and feldspar, while buckwheat does not make use of the latter. Sweet clover has a neutral or nearly neutral sap, while that of buckwheat is unusually acid, although it does not give off strongly acid excreta.

Sulphur as a fertilizer.

At the New Jersey station plats receiving 1,000 to 4,000 pounds of sulphur per acre gave a considerable decrease in the yield of barley, and the yield of soy beans following barley decreased sharply from 700 to 30 or 40 pounds per acre in plats receiving 4,000 pounds of sulphur.

At the Oregon station sulphur was found to cause greater nitrogen assimilation by legumes through the beneficial effect on nodule development, and the amount of sulphur taken up by the plant was limited by the total nitrogen absorbed. It was shown that the presence of nitrates influences the amount of sulphur taken up by the plant to form compounds containing nitrogen and sulphur. Rape, however, will take more sulphur than is needed for this synthesis, depositing the surplus as sulphate in the ash. An application of 100 pounds of sulphur every four years on alfalfa increased the yield over a ton per acre. While it seemed to supply a real deficiency, its most important effect was aiding nitrification by stimulating nitrifying bacteria. White, alsike, and red clover also responded well, while results with field peas and beans were less definite. Oats seemed to require a moderate amount.

At the Washington station elemental sulphur gave increased yields of wheat, oats, barley, and peas, and a striking increase in the yield of alfalfa was secured with gypsum. The sulphur content of Washington soils was found to be insufficient, especially for legumes. While gypsum produced no increase when applied to small grains, when used on legumes it not only increased the yield but produced a hay of higher nitrogen content. This would indicate that it acts more as a stimulant than as a plant food. Tests at the Texas station showed that the soils of that State have little or no need for additional sulphur, ordinary fertilizers usually containing sufficient.

Available iron.

Investigations at the New Jersey station show that ferrous sulphate is the most available and efficient form of inorganic iron in preventing chlorotic effects in plants grown in nutrient solutions, but became very toxic in media in which the H-ion concentration was maintained at a high level by the plant. In such media, ferric phosphate was found to be the most efficient source of iron.

Borax injury.

Tests with borax at the North Carolina station showed that as little as 1 pound of anhydrous borax per acre injured tobacco and no cotton would grow in pots of sandy soils containing it at the rate of

5 pounds per acre. In clay soils both corn and cotton showed marked injury when the amount of borax exceeded 7 pounds of anhydrous borax per acre, but the plants survived. Borax disappeared from the zone occupied by the roots with sufficient leaching. The New Hampshire station finds that borax is most liable to be harmful if applied in drills below the seed. Beans and corn were more susceptible than potatoes. Three pounds of anhydrous borax per acre was the greatest amount that could be applied with safety, in drills, to beans. The limit for corn was somewhat under 5 pounds and for potatoes slightly over 5 pounds. Lime, gypsum, or manure prevented some of the injury.

Preservation of barnyard manure.

At the New York State station acid phosphate was found to be the most efficient agent for preserving manure, among many substances tried. It not only held more of the nitrogen but also appeared to conserve the organic matter of the manure. Peat was also quite efficient, but soil, gypsum, and rock phosphate were of much less value. Straw greatly reduced the fertilizing value of manure.

Green manuring.

Studies in green manuring at the Virginia station showed that the younger the green crop turned under the better was the growth and color of the wheat grown. When the green manure crop (clover) was cut off and removed a yield of corn of 35.28 bushels was secured, but when it was turned under the yield was 40.5 bushels, with 17.76 bushels on the check plats with no green manure. With rye as the green crop, the yield on the cut-off plats, was 17.03 bushels of corn and on the turned-under plats 23.66 bushels. Using soy beans as the green crop and growing wheat, the yield on the cut-off plat was 21.97 bushels, and on the turned-under plat 26.94 bushels, with 17.33 bushels on the check plat. With buckwheat as the green crop, growing wheat, the cut-off plat yielded 13.64 bushels and the turned plat 16.66 bushels.

At the Mississippi station forest leaves, straw, pine needles, corn stalks, cotton stalks, alfalfa, and stable manure were turned under to get the cumulative effect, growing oats as an indicator. The forest leaves, corn stalks, and pine needles did not show any effect the first year, but a marked one the second year. A test of the amount of green manure that can profitably be turned under indicated that 40 tons of alfalfa to the acre gave the maximum results, being a little higher than where 60 tons were turned under. When the soil was limed, however, 60 tons gave the higher yield, indicating that one factor causing the decrease with that amount was acidity.

At the New York Cornell station, using as measurements the rapidity of humus formation, the accumulation of nitrates, and the increased availability of the plant nutrients, the subsequent plant growth indicated that the greatest rapidity of decomposition and the greatest benefits to the soil were secured by the use of green manures at the half-grown stage, this being true of the three crops tried—rye, oats, and buckwheat.

Miscellaneous.

It was shown at the New Jersey station that with fertilizer constituents well balanced for good growth and with approximately

optimum conditions of soil moisture, a medium or even a low fertilizer application has greater plant-producing value than a heavier application with the soil moisture conditions either above or below the optimum for plant growth.

Availability studies at this station have made it clear that it is not necessary for the farmer to pay more for nitrogen in the form of organic materials than in the form of nitrates.

FIELD CROPS.

Crop improvement.

The Oklahoma station has produced a selected strain of Kingfisher barley that has yielded at the rate of 54 bushels per acre, as compared with 35 bushels of the original variety.

Corn-breeding experiments at the Minnesota station indicate that high protein varieties can not be obtained which also have maximum yielding ability. The Nebraska station has found second generation hybrids in pure lines to be less productive than first generations, and that close relationship between pollen and silks is undesirable. Seed from first generation hybrids gave somewhat higher yields than the original corn.

At the Iowa station a strain of Reid's Yellow Dent has been developed to which the name Iodent has been given. In the State corn-yield contest this new variety stood seventh among 48 samples from the south-central section of the State. At the station it matures from 6 to 10 days earlier than the average Reid's Yellow Dent and promises to be of importance in certain sections of the State.

Six promising strains have been developed at the Connecticut Storrs station, in cooperation with the State station, which are being distributed. Early plantings gave the highest yield of dry matter. Results of inbreeding carried on for 16 years at the Connecticut State station show that this does not necessarily result in weakened strains and is a valuable means of plant improvement. The method used, devised by this station, involves the bringing together each year of four inbred strains, carrying the four stock strains, with the repetition of the crossing each year, since the corn grown from the double-crossed seed has no particular value for further planting.

The New York Cornell station has developed three promising strains, Cornell 11 and 12 and Webber's Early Dent. No relation was found to exist between score-card points, yields, and earliness. Early maturing Dents gave the largest quantities per acre and appeared best for silage.

In experiments with corn at the Mississippi station but little gains in yield were secured by crossing the varieties commonly grown. In one case an increase of seven bushels per acre was secured, but it often resulted in reduced yields. Most of the varieties themselves are hybrids.

In cotton-breeding experiments at the Mississippi station, while Mendelian numbers were not obtained with many characters, in crosses, they were obtained with lint, leaf color, and smooth or fuzzy seeds. Considerable success has resulted from the breeding and selection work, and some seed has been distributed that has yielded ½ bales per acre. An improved strain of Belton developed by the Texas station is being widely grown in some sections of the State.

In cotton-selection studies at the Arkansas station, "lint frequency," or "lint index" (the amount of lint on 100 seeds), rather than percentage of lint, is considered the proper basis to work from to increase the yield. It was found possible to increase the lint percentage, while the size of seed and length of lint were appreciably lowered.

Selection of cotton at the Alabama station has given an increased percentage of lint, but also susceptibility to anthracnose. A number of improved strains have been distributed and are being widely planted. A variety which is quite wilt-resistant is now almost exclusively grown in some sections. A comparison of the yield from light and heavy seed gave 742 pounds per acre for the latter and 600 pounds for the former, the checks yielding 636 pounds.

In acclimatization tests with cotton at the Mississippi station, in cooperation with the North Carolina and Texas stations, Mississippi grown seed produced slightly earlier, taller, and higher yielding plants.

Studies with flax at the Minnesota station have resulted in the production of high-yielding strains, combined with rust resistance. The North Dakota station has successfully crossed disease-resistant strains on nonresistant strains, retaining the good qualities of the latter.

The Iowa station has developed a high-yielding pure line pedigreed variety of oats to which the name "Iowar" has been given. This has yielded 8.8 bushels more per acre than other varieties with which it has been compared. The Kansas station has also developed a new variety which has given yields of 10 bushels over other varieties and has been named "Kansas Fulghum." Remarkably fine results have been reported by farmers with Idamine oats, developed at the Idaho station.

Selection of oats for higher yields at the Alabama station has been successful and improved strains are being distributed. Some hybrids have been secured which show considerable rust resistance. One strain is showing up well for hay, but the yield of grain is low.

Selected, treated, and certified strains of potato seed at the Wyoming station yielded 290 bushels per acre, compared with half that from commercial strains. At the Utah station the 1921 crop gave 156 bushels per acre of unselected, as compared with an average of 260.8 bushels for all selected strains, one of which yielded as high as 532 bushels per acre. Parent stock known to be diseased reproduced disease in 65 per cent of the progeny hills, as compared with 16 per cent for the progeny of undiseased parent stock.

An improved soy bean, Mammoth 152, yielding 7 bushels more per acre than the common Mammoth, has been distributed by the North Carolina station, and an earlier strain of Haberland 38 has been produced for the mountain regions.

The Connecticut State station has developed a new hybrid type of tobacco, a cross between Sumatra and Broadleaf, which has been fixed by selection and named "Connecticut Round Tip." This combines all the good qualities of the Broadleaf and Cuban varieties. More than 200 acres were grown in the State the past year, and it is meeting with great favor from practical growers. "Maryland Mammoth" tobacco, originated at the Maryland station, has given the

highest yield and sold for the highest price of any raised in the State. The Ohio station has developed a drought-resistant type of Montgomery seed leaf which is quite resistant to root rot and gives increased yields of about 30 per cent.

A new strain of wheat, named "Ashland," has been developed at the Kentucky station, which is being distributed. This averaged 2.3 bushels more per acre for seven years than the variety ordinarily grown.

At the North Carolina station seed of an improved strain of Leap's Prolific wheat, which has yielded 4 to 6 bushels more than the common strains, has been distributed in 22 counties with very favorable reports.

The Ohio station has produced a wheat-spelt hybrid which is wholly resistant to stinking smut, and attempts are being made to transmit this character in crosses with better bread wheats.

Common Federation wheat has outyielded all other varieties at the Idaho station and is being increased for distribution. A new variety has been found by the Utah station that has been tested both as a spring and winter wheat for dry farming. It has outyielded all others, surpassing Turkey Red by at least 25 per cent. It is being improved by pure line breeding. The Kansas station reports that the average increase in yield of Kanred wheat over other varieties for 10 years has been 4 bushels. In years when there is considerable rust among other varieties Kanred shows up still better. A summary of variety tests conducted at the North Dakota station for a number of years shows the general superiority of durum wheats as a class. Among the hard red spring wheats, Marquis was the best, but it is subject to rust. Kota showed a high degree of rust resistance.

Crop rotation.

In 30 years' experiments in crop rotation and manuring at the Missouri station the results show (1) that a four-year rotation of corn, oats, wheat, and clover gives the best results; (2) that crop rotation with no manure is practically as effective in maintaining the average yield in corn and wheat as is heavy manuring where these crops are grown continuously without rotation; (3) that averaging 30 years' yields, heavy applications of commercial fertilizers are as effective as heavy applications of barnyard manure in maintaining the total production in a six-year rotation of corn, oats, wheat, clover, timothy, and timothy; and (4) that rotation is more effective on the average than continuous cropping to grain crops, but is less effective than continuous cropping to grasses in maintaining the supply of soil nitrogen.

Experiments at the Wyoming station demonstrate the value of cultivated crops, especially potatoes, on the following grain crop. Summer fallow showed only slight gains, insufficient to cover expenses. In similar experiments at the Utah station peas and potatoes were more profitable when grown during the fallow period between wheat years than corn. Wheat after wheat, followed by an intertilled crop, was more profitable than where oats or barley took the place of one of the wheat crops. At the Washington station, when either vetch or peas were used as a green manure crop, the following crop of wheat produced only as high a yield as after good summer fallow, but the wheat was as high in quality. From an economic

standpoint, however, as far as immediate production is concerned, green manuring is not recommended.

In a study of residual effects at the Louisiana station a comparison was made of the effects on succeeding crops of cotton and oats of plowing under soy beans, crimson clover, cowpeas, and velvet beans. Velvet beans produced the largest yield of cotton for two years. When soy beans were introduced in a rotation of corn and cotton the yield of cotton was increased 100 per cent.

Corn culture.

The Montana station has conclusively demonstrated the great value of corn as a forage crop in dry farming in the higher valleys. It produces more than twice as much as any other forage crop grown without irrigation. In the lower valleys it is valuable both for grain and forage. It leaves the ground in excellent shape for a succeeding small grain crop, in many years being nearly equal to fallow.

The Missouri station finds that the character of the season is a limiting factor in the use of fertilizers for corn. If there is little rain during the summer the corn may be greatly reduced, but with good rains, well distributed, any system of application is profitable. With severe drought no application of fertilizers returned their cost.

A complete fertilizer applied in advance of the corn planter with a fertilizer drill at the rate of 300 pounds per acre gave the largest increase in yield, the second largest being from 250 pounds of a complete fertilizer drilled into the soil in advance of the planter and 50 pounds applied in the row at the time of planting.

In a trial of forms, rates, and carriers of nitrogen for corn at the Mississippi station nitrate of soda was best, 100 pounds giving an increase in yield of 16 bushels per acre. Two hundred pounds gave a little higher yield, but not enough to cover expenses. Sulphate of ammonia came next in efficiency, then cyanamid.

Tests at the Alabama station as to the best time to apply nitrate of soda to corn showed this to be when the plants are about 18 inches high. Similar tests at the Mississippi station gave better results when the application was made when the corn was very small. Corn that had been injured by too much rain showed a big improvement and gave paying returns where nitrate was used even when the corn was 2 or 3 feet high.

In tillage experiments at the Iowa station in which corn was cultivated only once or not at all the stalks were smaller in diameter and shorter and there was more smut than on cultivated plats. The amount of water utilized by weeds is of considerable importance, especially in times of drought. A comparison of deep and shallow cultivation at the Kentucky station showed little difference in the results, the shallow cultivated plats yielding 55 bushels and the deep 56 bushels. Cutting the weeds without cultivation resulted in a yield of 53 bushels.

In experiments at the Kentucky station, in which soy beans were planted thickly in the corn rows or in alternate rows, the combined yields of beans and corn were not as valuable as corn planted alone, but planting the beans at the rate of a hill to each hill of corn did not decrease the yield of corn materially, and the combined yield had a greater feeding value than the corn alone.

At the Louisiana station the greatest yield of corn and velvet beans was obtained when both crops were planted in the same row

Tests of varieties for silage at the Idaho station show a variation of yield from 8.53 tons to 22.39 tons per acre on the basis of harvesting 100 hills of each variety. A summary of 5 years' tests at the Kentucky station gave a yield of 10.35 tons per acre of corn for silage and of 16.15 tons of sorghum for silage.

Detasselling did not materially increase the yield at the Nebraska station.

By germinating the seed in an ice box the Wisconsin station has secured strains of corn resistant to cold which can be planted from 10 days to 2 weeks earlier than ordinary corn and which are proving popular.

The Minnesota station finds that respiration is increased in stored shelled corn by raising the temperature within certain limits, by increasing the moisture content, by the presence of broken grains and damaged kernels, and by the termination of a period of partial dormancy following harvest.

The Wisconsin station finds that when corncobs are partially hydrolyzed and the resulting sugar solution inoculated with the proper bacteria, about equal quantities of acetic and lactic acids can be obtained, 1 ton of cobs yielding about 300 pounds each of acetic and lactic acids. This apparently has large commercial possibilities, as the United States produces over 20,000,000 tons of corncobs annually.

Cotton culture.

Tests of cotton varieties at the New Mexico station showed Durango to be one of the best for the State, yielding equally as well as some of the more common varieties, and the price received for the lint was practically double that for the shorter staple.

The Alabama station finds the best time for applying nitrate to cotton to be when it is from 3 to 5 inches high. A test of the different forms of nitrogen at the Mississippi station showed very little difference in yield when the same amount of nitrogen in each compound was used. Potash experiments with cotton at the Georgia station, on a clay loam soil indicated that very small applications of potash were as beneficial as heavy ones.

Experiments in thinning, at the Texas station, show that if this is done late the results are harmful rather than beneficial, and where the moisture supply is adequate, with proper cultivation and freedom from competing weeds and grasses, cotton may be left more thickly in the row than is usually practiced. Results obtained at the Mississippi station indicate that much closer spacing than has heretofore been practiced gives decidedly bigger yields, especially under boll weevil conditions.

Very satisfactory results were obtained at the Arkansas station in delinting cotton seed with sulphuric acid and planting the seed with a corn planter. Sunburning was found to be a very common cause of shedding of bolls.

The Oklahoma station finds no critical period in the formation of oil in cotton seed during growth. Season has a marked effect on the oil yield. The latter is dependent chiefly on the total yield of cotton per acre, and there is no great variation in the oil content of mature seed of different varieties in the same year.

Legumes.

Sweet clover investigations at the North Dakota station indicate that this crop may be safely seeded in the Red River Valley over a wide range of time from early April to the middle of June. Ten pounds of seed per acre is sufficient. The Idaho station also reports that this amount of well-scarified seed per acre gave the best quality and yield of hay. Annual varieties were found to be not so well suited to the climatic conditions of northern Idaho as the biennial strains. At the Oklahoma station spring planting and sowing the seed shallow in a well-prepared seed bed gave the best results. Studies at the Michigan station show that if sweet clover is cut too close the crop is ruined. Cutting as the buds start to form but before they are open, at a height of about 9 inches, was apparently best.

The Wisconsin station has introduced a yellow sweet clover from Canada that is much finer in stem and more leafy than biennial white sweet clover and that matures earlier, making a fine grade of hay. It will grow well on a variety of soils and the seed yields are more than double the biennial clover yields. It promises to be a valuable forage crop for the State.

The annual white sweet clover, Hubam, has been widely distributed by the Iowa station and the reports have been most encouraging. It is believed that it will prove to be especially valuable as a green manure crop to seed with small grain in the spring and plow under in the fall, that it will make an excellent fall pasture crop for cattle and sheep, and that it will prove to be a satisfactory emergency leguminous hay crop to seed when red clover or alfalfa fail.

In germination tests of hard seed of alfalfa, sweet clover, and red clover, at the Montana station, treatments including hulling, two rates of scarifying, and sulphuric acid were tried, the latter giving the highest germination.

A new species of vetch (*Vicia dasycarpa*) has been found by the North Carolina station that is smoother than hairy vetch and free from disease. This is being increased for distribution.

In a comparison of inoculated and uninoculated soy bean plants at the New Hampshire station, all of the former showed a remarkable difference in color and in the number of root nodules as compared with the latter, and the leaves and stems contained 26 per cent more nitrogen.

The Oregon station reports that the Tangier pea, introduced by the United States Department of Agriculture from northern Africa, is proving an excellent silage crop, yielding 25 tons of green matter to the acre. A study of the water requirements of beans at this station showed, as a seven-year average, that 2,90[illegible] pounds of water was required for 1 pound of dry matter. When grown in rotation this was reduced to 2,249 pounds, and when treated with manure to 1,900 pounds. With irrigation, continuous cropping to beans gave a water requirement of 2,622 pounds, when irrigated and rotated 1,794 pounds, and when irrigated, rotated and manured 1,425 pounds.

The Minnesota station obtained good results in the inoculation of legume seeds by using the same number of pounds of inoculated soil as of seed. Reports from the Wyoming station show tha

good results were obtained by inoculation, especially on dry-land farms. The Wisconsin station found that this is not necessarily a growth factor, but results in an increase of nitrogen even when no increase in growth results.

It is reported by the Iowa station that it is necessary to inoculate for alfalfa on 90 per cent of the soils of the State, and that the application of lime is necessary in 70 per cent. Turkestan proved to be as hardy as Grim but gave lower yields, the latter giving four cuttings. The Kansas station reports that a decrease in yield of alfalfa followed all applications of over 200 pounds of sulphur per acre.

At the Kentucky station the organism in the nodules organism of soy beans was found to be entirely distinct from the alfalfa organism, and the two can not be interchanged. There is also a difference between the sweet clover and red clover organisms, but that of sweet clover is identical with that of alfalfa. Similar studies at the Wisconsin station showed that the organisms from alfalfa and sweet clover and from peas and vetch can be interchanged, but soy bean and clover cultures can not.

At the Wisconsin station the best results for nodule formation on legumes were secured in a slightly acid or neutral medium and no nodules were produced where there was much alkalinity.

Potato growing.

Investigations at the Maryland station showed a direct correlation between the size of the seed piece and the size of the sprout. In Irish Cobbler a direct relation was found between the dominance of the apical buds and the yield. When immature potatoes are planted it is found that they go through a rest period and become mature before growth starts. With late potatoes there is a transfer of starch from the large tubers to the small ones, if growth is checked, and therefore digging should be done as soon as possible after the tops are killed by frost.

The South Carolina station reports that successful potato seed production is largely a matter of the production of viable pollen and that environmental conditions also have an important bearing. At the Washington station 22 lots of Netted Gem potatoes for seed, secured from different localities in the State, varied in yield from 3,764 to 13,952 pounds per acre.

In tests of the use of dryers for potato seed pieces, those receiving no treatment resulted in less decay than those treated with gypsum, rock phosphate, or sulphur. The New York State station reports that plants from similar halves of the same tuber often differ widely in yield without apparent cause, showing that improvement by hill selection can not be carried to a high degree of perfection.

Tests at the New Jersey station showed that potato seed pieces larger than three-fourth ounce increased the yield. Evidence was secured that the more immature the tuber the better its purpose for seed. Similar results were obtained at the Pennsylvania station, the immature seed giving an increased yield. The Rhode Island station finds that good seed potatoes are high in nonprotein nitrogen compounds.

At the Nebraska station no degeneration was found where potato seed was grown with minimum irrigation, but it did occur under

the regular irrigation practiced. Under dry-land conditions seed can be maintained for a series of years without degeneracy. Under irrigation tubers have degenerated rapidly during a series of years and become practically useless for seed. Small tubers from high-yielding strains give as good results as large tubers. Tuber line strains grown on dry land and taken to irrigated land break up under one or two years of irrigation and are worthless after about three years. A comparison of seed from irrigated and dry-land sources gave a gain of 80.3 bushels per acre in favor of the dry-land seed stock. Western Nebraska seed was equal or superior in yields to seed from Minnesota and much superior to eastern Nebraska seed.

The Iowa station found high temperature to be the most important limiting factor in potato production in the Corn Belt. There was a difference of 50 per cent in yield in favor of early planting.

Sunflowers.

A number of stations have been engaged in a study of the sunflower as a silage crop, with results that demonstrate its value, especially in those sections where corn can not be depended upon to ripen. While its nutritive value and palatability are somewhat below corn silage, this is to some extent compensated for by the larger yields obtained. The New Hampshire station obtained a yield of 22.58 tons per acre, which was 70 per cent higher than the average yield of corn. The Oregon station reports a yield of 54.7 tons, green weight, per acre under irrigation. The Michigan station reports that special plates can be made for the corn planter which will handle sunflower seed satisfactorily. Mammoth Russian is the variety recommended by practically all of the stations.

Date and rate of planting have been tested at a number of the stations, early planting being recommended. At the Michigan station the best results were obtained in planting from May 15 to June 1 and 6 to 8 pounds of seed to the acre, in rows 30 to 36 inches apart gave the maximum yield and the best quality of silage.

At the Idaho station 8-inch spacing produced a tonnage 68 per cent greater than 30-inch spacing. The Minnnesota station reports that close planting gave a better quality of silage, which was less coarse, woody, and fibrous than that from wider spacings, and also notes the fact that early plantings give the highest yields. At the Nebraska station early plantings gave twice as much tonnage as corn, but the yield fell off rapidly with later plantings. Such early plantings, however, were found to be attacked by a leaf rust, which greatly reduced the quality of the silage. The Oregon station recommends seeding with a grain drill in rows 21 inches apart at the rate of 25 to 35 pounds of seed per acre. The Wisconsin station reports the best results when not planted closer than 6 inches apart in drilled rows.

At the North Dakota station sunflowers made much more growth in the same length of time than corn, and withstood prolonged cool weather better, even considerable frost in the spring.

In harvesting, the Nevada station recommends cutting when the crop is about 50 per cent in bloom, for if left longer birds get much of the seed. The Michigan station reports that sunflowers should be cut for silage when from one-tenth to one-third in bloom. Ordinary corn-harvesting machinery was found to be satisfactory

for harvesting sunflowers. The Oregon station recommends harvesting any time from full bloom until the seeds are in the stiff dough stage. At the Wisconsin station the best results were obtained by cutting when the plants average one-third in bloom, the silage from early cuttings being eaten readily with no decrease in milk flow, although somewhat more acid than corn silage.

No advantage was found in planting corn and sunflowers together in the row, but by planting alternately two rows of each good results were obtained.

Determination of the plant food removed by this crop at the Montana station shows it to be a heavy feeder, especially of potash. It is not recommended as a silage crop for the State by the Pennsylvania station, except in such localities where corn is not a sure crop. The silage showed a distinct lack of palatability, and cattle did not relish it as well as a good grade of corn silage, and cows produced only 86.4 per cent as much milk on a ration containing a normal amount of sunflower silage as compared with a good corn silage. At the Oregon station, however, it is noted that stock left choice alfalfa hay for sunflower silage. It was improved by silaging with corn or oats. The effectiveness of the sunflower crop in controlling weeds is noted at the Wisconsin station.

weet potato storage.

Observations at the Mississippi station on sweet potato storage how that well-cured potatoes can be carried as low as 32° F. withut damage. Potatoes left in the ground three days after a killing rost will not keep and are not fit for food. Similar studies at the labama station show that temperature, even that above the frost oint, seems to be a factor in the keeping quality. If harvested efore frost the results have been good, but if the vines are cut or illed the potatoes will not keep.

obacco culture.

The Massachusetts station finds that tobacco reaches its best delopment on soils showing a medium lime requirement. The results f studies at the Virginia station indicate that it is best to grow right tobacco on a poor soil and add the necessary plant food, as e tobacco tends to be dark if the soil is too rich. The best results ere obtained with a rotation of tobacco, wheat, and redtop. In a udy of sources of nitrogen for bright tobacco, the best results were tained with inorganic forms, for the first year at least. The North arolina station reports that a small amount of magnesia in fertiers prevents what is known as "sand drown" in tobacco.

Studies at the Kentucky station on the tolerance of tobacco to dium nitrate concentrations show that with concentrations greater an 1 part to 3,750 parts of water the plants begin to wilt, and the concentration reaches 150 parts to 3,750 the injury is pernent. The best general results were obtained with a strength of to 3 parts to 3,750, the plants soon recovering from the initial ooping. It is also found that if heat can be properly applied in ge barns at an economical cost, losses due to unfavorable weather curing time can be eliminated and the average quality of the cured f improved. Studies on the cost of production showed that on average of 81 farms in the Burley district, 375 hours of man

labor and 98 hours of horse labor were required to produce and market an acre of tobacco. For the dark-fired tobacco the labor was 26 hours of man and 6 hours of horse labor.

Wheat culture.

The Maryland station reports that 70 per cent of the wheat acreage of the State is of the higher yielding varieties introduced by the station, and it is estimated that 1,500,000 bushels have been thus added to the annual yield.

At the Minnesota station large ungraded and small wheat seed, sown at the same rate per acre, gave equal yields on both medium and highly productive soils. Seedings of winter wheat from September 1 to 10 gave higher yields than those made later.

Tests at the North Carolina station showed that earlier plantings, up to October 1, of wheat gave better early growth, but all were damaged by rust. The best results were obtained with both crops from plantings from October 1 to 30 and with 80 pounds of seed to the acre. The Virginia station also reports that early seeded wheat is attacked by rust more than is late seeded. Two good strains of wheat were developed and distributed.

Tests at the Washington station show that where nitrates are not limited the lightest seeding of winter wheat produces the greatest amount of tillering. This, however, is not strictly inversely proportional to the rate of seeding, but the heaviest seeding produces the greatest number of culms per unit area. The number of culms per acre can therefore be controlled in part by regulating the rate of seeding, a matter of practical importance from the standpoint of its effect on lodging and "burning."

At the Idaho station applications of sodium nitrate, ammonium sulphate, or hydrolyzed wheat extract, or of potash and phosphorus to poor soils, increased the protein of wheat. The experiments showed the important part that a liberal supply of available nitrogen in the soil plays in the elaboration of protein in the wheat kernel. Studies at the California station show that the time of application of nitrogen to wheat has a direct influence on the hardness. There is also a varietal difference in the response of wheat to nitrogen. Tests at the Washington station show that with a good supply of nitrogen a much smaller amount of seed than otherwise would be required will give a good stand. Cultural experiments with winter wheat showed no consistent advantages from harrowing the crop in the spring, and while in some instances the harrowed crop equaled the unharrowed, it was not superior, and in many instances was less.

At the Rhode Island station wheat, grown in plats that were neutral in reaction and receiving nitrate of soda, was chlorotic, abnormal, and yielded only 11.3 bushels. On plats not quite neutralized and receiving ammonium sulphate the plants were of the normal green color and yielded 23.1 bushels, indicating that slight acidity is desirable for this crop.

Samples of frosted wheat, at the Montana station, showed poorer baking qualities than unfrosted, but after a few months of aging the baking quality of the frosted samples was greatly improved. On separating some of the amino compounds from severely frosted wheat, and adding these to good flour, a larger loaf and better texture were obtained.

The Minnesota station has found that the ratio of gas produced in doughs to the gas diffused out of such doughs is a useful basis of evaluating flour strength.

Oat culture.

The Alabama station reports that applications of acid phosphates to oats appeared to increase somewhat resistance to winterkilling, but had little effect on yield. Continuous planting of fall and spring oats with seed from the same source for both plantings, which has been carried on for 17 years, shows the fall plantings to give slightly higher yields, but the spring plantings were four or five days earlier.

At the Minnesota station small oat seed gave decidedly less yield than large or ungraded seed, when the same number of seeds per acre were sown. Large and ungraded seed gave approximately the same yield when the same number of pounds per acre were sown. Primary kernels yielded more than secondary kernels.

Tests at the North Carolina station showed that earlier seedings of oats gave better early growth.

Studies on the lodging of grain at the Ohio station show that when oats are seeded above 9 pecks to the acre they lodge badly, which is also the case when small seeds are used. Commercial fertilizers and heavy manuring also caused lodging. It occurred particularly in thick stands, and the diameter of the straw was found to be less under these conditions. Plats of shaded grain lodged in a windstorm which unshaded grain withstood. The grain also went down worse on plowed plats than on disked ones, and it is noted that in the former more nitrates were produced. Weak stems were found to stool more abundantly.

The Virginia station has developed and distributed a good strain of oats.

Seeding grain.

Very early seeding of grain was found to be preferable at the Wyoming station, both from the standpoint of moisture and of early maturity. While the early seeded grains make little growth the first few weeks, they ripen earlier, escaping early frosts. Wheat, oats, and barley seed were found to germinate well when cut at an early stage of maturity.

At the Minnesota station a mixture of early oats and barley yielded more than either crop alone. Medium-maturing oats alone produced more pounds per acre than the early oats alone or in mixture with barley. Wheat and medium-maturing oats mixed yielded less in pounds per acre than oats alone, but more than wheat alone.

Improvement of pasture.

At the Nevada station the improvement of old pastures in the Humboldt Valley has been very successfully accomplished by cutting down the irrigation water, which was causing a growth of the coarser grasses and sedges, and by shallow plowing and disking. A shortage of water produced no unfavorable effect upon the wild grass, and under intermittent irrigation the yield of the more desirable grasses and clovers was increased.

At the Florida station Bahia grass is proving promising for summer pasture, growing well on light sandy soil and improving the grazing. It is, however, killed to the ground by frost.

Weed eradication.

Quack grass was successfully eradicated on two infested fields at the Wisconsin station by growing Sudan grass. At the New Mexico station chemical treatment for the eradication of Johnson grass was not found profitable. Close pasturing with goats, after which the field is plowed, all roots and stalks raked out, and the field planted to cereals, has given the best results. From nine years' study at the Iowa station the most resistant weed seeds were found to be butterprint, curled dock, jimson weed, horse nettle, five finger, and the honey locust tree.

Experiments at the Minnesota station showed that good cultural methods are an economical way of controlling and eradicating the perennial sow thistle.

Miscellaneous.

A comparison of black-hull kafir and corn by the Missouri station on the thin dry soils of the Ozark region showed an average yield of the former of 27.9 bushels of grain, compared with 7.7 bushels of corn.

A strain of feterita, named "Spur," that yields over 7 bushels of seed per acre more than the parent varieties, has been developed at the Texas station.

Crop irrigation studies at the Utah station show that sugar beets require 27 to 33 inches, potatoes 21 to 27 inches, and alfalfa 30 to 36 inches in four or five applications. Transpiration and evaporation losses were found to be very great, 4 acre-feet being the maximum for alfalfa.

Tests by the Arizona station show that Sudan grass is successful in all parts of the State at elevations below 6,000 feet and of limited value at higher elevations.

FRUITS.

Improvements of fruits.

Studies at the New York State station show that the most effective course in breeding for the development of fruits is to use as a male parent a seedless fruit, which is usually strongly staminate, on a nearly seedless fruit which does produce a few viable seeds.

Extensive apple-breeding experiments at the Idaho station have resulted in a cross between the Wagener and Ben Davis, which is at least a month earlier than the Wagener and has a season extending beyond the Wagener. A new apple variety of great promise has been developed at the Iowa station, which has been named the "Ames." It has a good red color, is vigorous and hardy, of excellent quality, productive, and of good keeping qualities.

The Oregon station has developed a cherry seedling that is vigorous, a heavy bearer, free from gummosis and from freeze injury, that promises to be of value. At the Mississippi station a cross has been secured between the cherry and plum that gives indications of being of great value.

A promising seedling prune has been developed at the Oregon station, bearing a fruit with a higher sugar content than any variety tested. It is a freestone and is excellent for drying.

At the California station a Persian variety of grape, Black Monukka, has been found especially valuable as a table and raisin

grape and is a heavy bearer. The fruit is being shipped to New York from the Imperial Valley as a table grape.

At the Oregon station cross-pollination of the strawberry had no effect upon yield, earliness of maturity, or quality of fruit, and the Vermont station finds indications that self-pollination has little or no effect on quality, but does have some on size and earliness of the fruit. Blackberry studies at the latter station indicate that a species which responds to both the recognized systematic and genetic criteria for species may arise as the result of hybridization. A raspberry-dewberry cross originated at the Texas station is being distributed and promises to become of economic importance. It has been named the "Ness," in honor of its originator. The fruit is large and attractive in color, of good quality, and an abundant bearer. It crosses readily with all species of Rubus and the progeny are self-fertile. At the New Hampshire station a high-bush cranberry is being introduced as a substitute for gooseberries and currants, which are being eradicated to save the white pine of the State.

Fertilizers and cover crops.

Delaware station experiments on fertilizers for the apple orchard show that every kind used has uniformly increased yields, although increase in yield has not kept pace with increase in the amount of fertilizer used, indicating that moderate fertilization is most economical. At the West Virginia station applications of nitrogen are showing marked effect in both vegetative growth and fruit production.

Studies at the Michigan station showed that the poorest results in the limed portion of the orchard were better than the best treatment without lime, as far as growth and some other factors were concerned. Trees grown under control at the Wisconsin station showed an increased nitrogen content in the new growth where nitrate was applied liberally, and it is believed that fruiting depends on the optimum relation of nitrogen supplied from the soil and the amount of carbohydrate material which the leaves can construct.

In experiments at the New Hampshire station, plats receiving fertilizer in addition to cultivation and cover crops showed the greatest growth as measured by trunk diameter and twig growth. The yield from the fertilized plats was 50 per cent higher than from the unfertilized, and it is believed that the bearing is more regular in the former. Analysis showed shaded trees to be higher in moisture and total nitrogen and lower in free reducing sugars and starch. The effect of shading is most noticeable in the amount of carbohydrates synthesized by the leaves and stored in the fruit spurs. Girdled trees were lower in total nitrogen and moisture and higher in free reducing sugars and sucrose than ungirdled. Fruit-bud formation was increased in the girdled trees.

The Pennsylvania station finds that apple orchards in sod can not be conducted at a profit without the use of nitrogenous fertilizers. Those under clean culture gave practically no response to such fertilizers. The addition of 150 pounds of nitrate of soda per acre to sod orchards as a rule gives large increases in yield, but the use of mixed fertilizers has not paid the cost. Northwest Greening trees in clover sod, at the Iowa station, for a period of 10 years have produced 3 bushels more per tree than those on continuous blue-grass sod. The latter produced terminal growth which lacks sufficient

vigor to form lateral fruit buds necessary for fruit production in succeeding years, and the buds at the base of the leaf seldom have strength enough to push out growth the following year. Sunlight was also found to be an important factor, trees having the greatest exposure being the heaviest producers.

The Maine station finds that the development of the apple depends on the food supply available and on the seed content. Dropped fruit contains fewer seeds than the fruit remaining on the tree.

The Washington station finds that lack of complete fertilization of the blooms is a contributory factor to the June drop of apples.

Peach fertilizer experiments at the Virginia station showed that nitrogen and potash give the highest yield, nitrogen and phosphorus next, and nitrogen alone, next, but there is a difference in varieties in this respect. Phosphorus alone did not give any effect at first, but is beginning to show effects after two or three years.

At the Arizona station the air temperature was found to be 6° to 8° F. lower, the soil temperature 5° to 7° lower, and the humidity of the air 10 to 15 per cent higher in cover-cropped orchards than outside. Cowpeas as a summer cover crop caused grapefruit to retain their green color during the winter.

Applications of nitrate of soda to Satsuma oranges, at the Alabama station, gave a 100 per cent increase in yield, but the quality of the fruit grew poorer with the increase.

Hardiness.

At the New Hampshire station there was found to be little difference in the amount of injury done by exposure for different lengths of time to a temperature of —7.8° C. A markedly greater injury was done to roots by freezing them rapidly than by slowly lowering the temperature. Greater injury was done in wet than in dry soils. Air-dried roots showed less injury than normal, turgid roots. Some seedling roots were more hardy than others.

A hardiness factor for the apple has been worked out by the Iowa station by combining the depression of the freezing point and the moisture percentage, the best time to determine these being during the blooming period. A trial of Grimes Golden on about 20 different hardy stocks showed a wide difference in the amount of growth, depending upon the type of graft union made by the scion with the stock.

Winter injury to fruit trees has been investigated at the Washington station and is believed to be due to lack of sufficient nitrates to resume normal growth in the spring. Two factors seem to be involved, a soil solution heavily charged with mineral salts and an extremely fluctuating nitrogen content of the soil. The trouble is more noticeable in semiarid soils. Nitrification takes place in the fall and spring, but in May the soil moisture decreases, nitrification slows up, and the leaves do not develop normally, but form rosettes at the end of the twigs. The application of nitrate of soda gave some improvement in the succeeding year and the plowing in of clover corrected the difficulty.

At the Missouri station a correlation has been found between the pentosan content and hardiness of shoots from fruit plants. The study indicates that pectin-like water-soluble pentosans are the most important water-holding substances in the tissues of fruit plants

Similarly, histological studies of apple leaves at the Colorado station indicate that winterkilling injury is not due so much to freezing as to drying out of the tissues.

At the Nebraska station scion roots were found to stand a lower temperature than the roots of the French crab used for stock, indicating the desirability of propagating so as to get as many roots as possible from the scion. The critical temperature for apple roots is found to be from $-6°$ to $-10°$ or $-12°$ C. In making crosses with the object of increasing hardiness, the South Dakota station has secured a wild crab apple from Minnesota which is giving very promising crosses with several apple varieties, some of which are being propagated for distribution. New pear hybrids have also been secured which are hardy and withstand blight.

Sterility in apples.

Studies of the cause of sterility at the West Virginia station show that in some varieties so many pollen tubes grow down into the pistil that fertilization can not take place. This is true with Rome and Rome pollen, but not to the same extent with other pollen.

At the California station Gravenstein and Spitzenberg were found to be largely self-sterile, Jonathan giving the best results for the pollination of Spitzenberg, and Delicious for Gravenstein. Belleflower was also found to be practically self-sterile.

Setting of fruit.

Fruit-bud formation has been studied at a number of stations. The Virginia station finds this to be about equally affected by cultivation and nitrogenous fertilizers, but in different degrees. In general, cultivation gives better results than fertilizers. Results at the Missouri station show that the amount of growth is closely related to fruit-bud development. When spurs have attained bearing size the nitrogen content is considerably increased, and this also seems to be true of phosphorus. Spring applications of sodium nitrate gave no indication of an increase of nitrogen in the bark or spurs, while fall applications did increase the nitrogen in the bark. Starch accumulation was found to be greatest during June when the highest percentage of fruit-bud differentiation occurs, and these spurs are characterized further by a rise in the total nitrogen content of the two-year-old wood.

A study of the composition of fruit spurs by the Wisconsin station shows them to be rich in glucose, with less xylose and a little galactose. The hemicellulose disappears quite rapidly from the fruit spurs at the time the fruit is being formed, and is laid down quite rapidly when the leaves begin to function. The capacity of an apple tree to fruit seems to depend not only on the number of fruit spurs formed, but also on the amount of hemicellulose material.

Studies at the Oregon station on defoliation show that the setting of fruit is almost exactly proportioned to the number of leaves left on the tree. Irregular shaped apples generally lack seed in some of the carpels.

It is found at the Maine station that bud variation plays only a very small part in the yield, which may be largely due to the kind of stock and the soil in which the tree grows.

Identifying varieties.

Data have been secured at the Massachusetts station whereby the trueness to name of certain standard varieties of fruit trees may be determined from their growth in the nursery row.

Pruning apples.

Pruning experiments at the Virginia station demonstrate that a high head type of pruning delays maturity and reduces size, and heavy heading prevents bud formation. Summer pruning was disastrous, weakening the growth as well as preventing fruit bud formation. On unpruned trees the bloom comes on the fourth year's growth; on trees well thinned and headed lightly, on the fifth year's growth; and with normal pruning, on the sixth year's growth. Apple trees show decided differences in character of growth with differences in fertilization and culture.

Pruning studies at the West Virginia station showed that great variations in leaf structure results from different methods of pruning. Leaves formed after early pruning are found to have more of the palisade layers of cells. Different pruning methods also affect differently the development of the root system, which bears a close relation to the top, trees with large above-ground growth having a large number of feeding roots. Pruning dwarfs the trees, and while heavily pruned trees made the best growth at first, after three years they fell off rapidly. The dwarfing effects of pruning on the tops were accompanied by a dwarfing of the root system. Early summer pruning dwarfed the trees more than heavy dormant pruning. Long pruning has been found to be best for olive trees at the California station.

Fruit storage.

In apple storage studies at the Iowa station it was found that "Jonathan spot" develops largely in late picked apples, and that early picking and immediate storage will almost entirely eliminate it. Circulation of air in the storage room by the use of small fans prevented soft scald in the Jonathan apple. On the other hand, early picked or immature Grimes Golden developed scald badly in storage. They should be picked when as near maturity as possible, stored immediately, and the period of storage should not extend much later than January 1.

At the California station it was found that too high temperature in many cases delays the ripening of some varieties of fruit. Normally matured fruit was found to hold up better in flavor, color, etc., in storage. Fruit that had been picked green was found to keep better at a temperature of 36° F. For avocados the best results were obtained at 45°, the fruit not ripening well at a lower temperature. The color and flavor of such fruits as cherries, berries, figs, etc., were maintained for a year or more by freezing, but the texture softened somewhat, except with figs and cherries. A slight addition of sugar resulted in better retention of the color and flavor.

Peaches.

The Georgia station emphasizes the necessity of keeping the peach orchard in a good, clean, healthy condition, pruning out the mummies and cankered wood, and cutting out near-by plum thickets.

By these means it is found possible to nearly eliminate the curculio and brown rot, for which spraying or dusting alone should not be depended upon.

In fertilizer tests with peaches at the Illinois station the number of flowers per spur was increased and there was a better distribution on the shoots when potash was applied.

Cytological examination of a large amount of material at the Delaware station gives no evidence that June drop is caused by improper or incomplete fertilization.

The Maryland station finds that the dormant period of the peach bud ends about January 1 in that State, and as the temperature rises above 43° F. growth begins. There is a direct correlation between the air temperature and the moisture content of peach buds.

At the Arizona station the actual water requirements of individual peach trees during the first growing season of seven months was found to be 190.25 gallons.

Grapes.

Early fall pruning of grapes by the South Carolina station produced no injury when sodium silicate was applied to the cut surfaces to prevent bleeding. The Georgia station found root grafting to offer the greatest possibilities in facilitating root formation of muscadine cuttings.

Pecans.

The Georgia station finds that the early dropping of pecans is at least partly due to faulty pollination, with indications of a possible remedy in soil treatment. Pecans under cultivation gave a 50 per cent better crop than those on sod at the Mississippi station. The New Mexico station has a number of varieties that are beginning to bear, and it is believed they will be a successful crop for the Southwest. All varieties of filberts tested at the Oregon station were self-sterile, necessitating cross-pollination.

Vinegar from frozen apples.

The Iowa station reports that a good grade of vinegar can be made from frozen apples. The formation of acid was found to begin before alcoholic fermentation was complete.

VEGETABLES.

The North Dakota station has developed an improved strain of Earliana tomato that has been distributed to growers, some seed houses making a specialty of it. At the Oregon station 80 per cent of pollinated tomato blossoms produced marketable fruit, as against [illegible]0 per cent on unpollinated plants. No advantage was found by the New Mexico station in forcing tomatoes in cold frames, except for extreme earliness. For the main crop, field-planted tomatoes proved best and appeared to be less subject to disease. Fertilizer experiments with tomatoes, at the Missouri station, showed phosphorus to be the limiting element of plant food, and when the supply of nitrogen becomes limited blossoms fail to set fruit.

The Louisiana station reports that sweet corn may be so planted, using Stowells Evergreen and Howling Mob, that it may be had over a period of 10 to 12 weeks. At the Iowa station there is found to be

a greater variation in the sugar content between sweet corn processed immediately and that held for 24 hours than there is between the lots from the various seed sources when processed and handled under identical conditions. As sweet corn passes from the stage in which it is graded as extra standard pack to the substandard grade, the pericarp undergoes a thickening of the cell walls, making it about three times as tough.

Fertilizer experients with celery on muck soils, by the New Jersey station, indicate the advantage of using a moderate application of fertilizer mixtures low in nitrogen, high in phosphorus, and low in potash, such as a 2–10–4 or a 4–6–6 mixture.

At the Maryland station studies in onion dormancy showed no growth in storage at a temperature as low as 30° F., but considerable evidences of internal growth at 40° F. There was a dormant period of from 6 to 8 weeks, after which growth was resumed. Transverse cutting of the bulb started growth, the time when this was resumed being proportional to the nearness of the cut to the growing point.

In work with beans at the New York Cornell station, selection within pure lines, for size and shape of seed, for several generations did not change these characters nor did it have any effect in changing the size of the eye in yellow-eyed beans.

Canning spoilage.

Canning studies at the Colorado station with corn and peas processed for different periods at the boiling point of water (94.5° C. at the station), showed that spoilage was greater with corn than with peas under the same conditions of treatment. Spoilage resulted in all of the peas heated less than three hours and in all of the corn even when heated for five hours.

DISEASES OF PLANTS.

Apple diseases.

In studies on the root rot of apples at the Virginia station Northern Spy was found to be the most resistant variety, the percentage of infection being only 17 as compared with 78 in seedlings. The organism most commonly present is *Xylaria digitata*, often accompanied by *X. polymorpha*. It is not believed that an infected tree can be cured, the best treatment being to replace with Spy roots. It usually kills the tree in from 6 to 12 years. Dusting experiments for the control of the scab showed sulphur to be superior to copper dusts. None of the dusting materials used proved sufficiently effective in the control of bitter-rot of the apple to warrant their use.

One hundred per cent control was secured at the Massachusetts station in spraying for the control of scab and black rot of apples, when this was thoroughly done. The new growth must be kept covered with spray ahead of the ejection of the spores. At the Minnesota station excellent results were obtained in the use of sulphur dust in controlling apple scab and other apple diseases, and it can be applied much more quickly than sprays.

Life-history studies of apple rust at the Virginia station show that it spends 3 months on the apple and 21 months on the red cedar, which it occasionally kills. It also occurs on the wild apple. The

West Virginia station reports that territory where cedar eradication was carefully carried out is practically free from rust, adjacent territory suffering great losses.

The New York State station has shown that the fungus *Nummularia discreta* is parasitic and is the cause of apple blister canker. Indications point to the mountain ash and other plants as intermediate hosts. A coat of shellac followed by coal tar is found to be the most satisfactory dressing for priming wounds. At the Iowa station this trouble is observed to be a secondary infection on trees which have been injured by winter drought, overproduction, or anything which lowers the vitality of the tree. For treatment this station recommends cutting out the cankered portion and painting the wound with white lead and raw linseed oil containing 1 ounce of mercuric chlorid to 2 quarts of paint.

At the Oregon station one spraying with Bordeaux mixture in August gave almost 100 per cent control of apple anthracnose. The Washington station reports that apple rosette is rapidly disappearing with better irrigation, the use of fertilizers and cover crops, and pruning.

Peach diseases.

The Georgia station finds that brown rot of peaches starts as a blossom blight in the early varieties. The mummies remaining on the trees over winter produce conidia and the early maturing varieties are attacked. It spreads especially after rains.

The Delaware station has made extensive studies of peach yellows and little peach. No great difference was found between the anatomical structure of healthy and diseased tissues, but striking differences were found in the storage products of metabolism, diseased tissues showing a much higher starch content and more crystals in the corticular tissues. Gum plugging of the cells of the medullary rays was very evident in diseased wood. Blossom buds of the "yellows" shoots showed much earlier maturity of pollen mother cells than in healthy buds.

At the Virgina station sulphur proved superior to copper dusts for control of scab.

Citrus diseases.

At the California station the bacteria causing citrus blast has been found to have a low optimum temperature and to disappear with the advent of hot weather. It may be controlled by spraying early in November with Bordeaux mixture. It has been found possible to induce a number of orange diseases by the use of chemicals. A lack of lime results in the dropping of the leaves, which are more or less chlorotic. The bacterial gummosis of stone fruits has been found on peaches and on nursery stock.

The Florida station reports a varietal resistance of citrus to melanose. The pineapple orange is badly affected by this disease, but has practically no stem end rot. Avocado scab was found to be the same as citrus scab and the disease appears to be spreading to other hosts.

Other fruit diseases.

Studies on Sclerotinia, at the Maryland station, show that a period of dormancy is not essential in the life cycle of *S. cinerea*, and that

apothecia are formed on fallen fruit during the first season. These appear to be strains of *S. cinerea* with differences in cultural behavior and response to temperature, but no morphological differences have been recognized.

Spraying apricots for brown rot has been satisfactory at the California station, if the application is made at the time the petals are beginning to open.

The Wisconsin station has successfully controlled cherry leaf spot, which has been quite serious, by three applications of Bordeaux mixture 3–3–50, applied (1) just after the petals fall, (2) about two weeks later, and (3) soon after harvest.

At the Arizona station three species of fungi and one of bacteria were isolated from rotting dates. Species of Alternaria and Macrosporium appeared to be the dominant parasites. The leaves were found to be affected by the fungi and the disease is believed to spread from them to the fruit.

The results of studies on anthracnose of black raspberries, at the Wisconsin station, show that two sprays, one a delayed dormant spray of lime sulphur, 1 to 10, or Bordeaux, 6–6–50, after the first two or three leaves have unfolded, and a summer spray of lime sulphur, 1 to 40, or Bordeaux, 3–3–50, about one week prior to blossoming, with the addition of an adhesive, give good commercial control.

A study of pineapple diseases at the Florida station shows that new slips are apparently more resistant to wilt than old plants. Sterilization of the soil and fertilization have been of no value in controlling the disease. Slips from healthy plants from other localities do better, and those fumigated with hydrocyanic acid do better than unfumigated ones. There are some indications that the disease may be caused by improper breeding and running down due to poor selection.

The California station finds that walnut catkins infected with blight can carry the disease through their pollen.

Corn root rot.

Root rots of corn have received attention from a number of the stations. At the Indiana station tests were not successful in producing root rot by inoculations of the organism where there was no injury to the tissues at the nodes by metals, especially aluminum which combines with the proteids and causes discoloration and decomposition. Iron and aluminum in the soil seem most injurious when there is a deficiency of calcium or phosphate. The stalks may break down and fail to grow even if the organism does not gain entrance. The trouble is considered largely a result of physiological disturbances. The disease may get into the kernels which may then carry infection. Plants having the highest metal intake are most subject to the disease. There seems to be a possibility of developing resistant strains by selection and breeding.

The Illinois station finds change in the H-ion concentration of the sap a result and not the cause of root rot. Rainfall has considerable influence on the alkalinity or acidity of the sap. At the Delaware station four corn diseases are found to be carried internally in the seed, all of which may cause root rot. Forty per cent are found to be infected with *Cephalosporium sacchari*, 20 per cent with

Fusarium moniliforme, 6 per cent with *Gibberella saubinetii*, and 5 per cent with *Diplodia zeae*. Scab of wheat was found to be an important cause of root and ear rot of corn, and is transmitted through internal infection of the seed. Corn should not, therefore, directly follow wheat.

The Arkansas station has studied a bacterial root and stalk rot of corn that was affecting quite an area over the State and in neighboring States. An organism which resembles that described by Burrell about 1890 was isolated, and inoculation experiments showed it to produce a rotting of the roots and stalks at the nodes and a spotting of the leaves.

It was found at the Kentucky station that *Fusarium moniliforme* was present in practically all seed corn. Partial control may be obtained by using only ears the seedlings of which show a high degree of resistance to the rot when tested. Plants which ripen their ears at the usual time but remain green for a period following ripening, are found to produce more resistant seedlings than those which die previous to or at the time of ripening of the ears.

The Louisiana station also reports the widespread occurrence of *F. moniliforme* as a cause of root rot, and that a white flint corn has been developed which is quite resistant. It is thought that the same organism causes root rot of sugar cane. Its effect on corn is to stunt the growth, diminishing the yield about 50 per cent.

Corn ear mold.

Studies on corn ear mold, at the Iowa station, show that the dry-rot organism will only thrive under conditions of excessive moisture and high temperature. It grows best at a temperature of 86° F., and shows no growth at 55° F. There is little evidence of systematic or continuous infection from the roots up to the ears.

Cotton diseases.

Cotton anthracnose, which formerly caused a loss of from 2 to 5 million dollars annually in South Carolina, is now practically under control, with negligible losses, largely as a result of investigations at the South Carolina station. Preliminary drying and one-year storage of the seed apparently will control this trouble. The angular leaf spot of cotton was also studied by this station, which finds it to be seed borne and not carried in the soil. Absolute control is secured by delinting the seed with sulphuric acid and treating with mercuric chlorid, which also reduces the infection from anthracnose and insures quicker germination. The disease is spread by rain but if fields are separated by corn it will not spread in this way.

A new disease of cotton, noted by the Arkansas station, is found to be due to a *Phoma* sp. The organism has been isolated, its life history worked out, and its pathogenicity established by inoculation experiments.

The Texas station finds that the organism causing Texas root rot, *Ozonium omnivorum*, carries over winter not only on fleshy roots, such as sweet potatoes, carrots, or beets, but also may live over on cotton plants, the roots of which remain alive during the winter. Indications are that it is not carried over in the soil. These facts suggest effective means for its eradication. Studies of resistance

showed that guar (*Cyamopsis psoralioides*), an Indian legume, is completely immune.

Mosaic disease.

Investigations at the Iowa station indicate that the mosaic of Cucurbitaceæ and Solanaceæ are different strains, as they have not been successfully cross-inoculated, but they can be cross-inoculated between members of the same order. The disease may overwinter on the common wild ground cherry. Outbreaks of mosaic on tomatoes have been noted, accompanied by outbreaks on near-by wild species of the ground cherry. Field roguing and simple hand dusting machines, such as are used for combating insects, will hold it in check.

Investigations by the Louisiana station show that mosaic of sugar cane is world-wide in its occurrence, and selection seems to be the only promising means of control. The selection of disease-free stalks for propagation has been quite successful. L 511 is the most resistant variety found as yet. The disease occurs on corn and is more severe on that crop.

Studies at the Georgia station show that pepper mosaic attacks both pimento and bell peppers. Its transmission by insects, especially the spinach aphid, the green and pink potato aphid, and probably others, is well established, and spraying for these insects is advisable. Wild host plants have not been found as yet. Further studies showed mosaic of Lima beans to be transmissible in the seed, and that different strains of the same variety of potatoes differ in susceptibility. Rosette of prunes is also a mosaic disease and is infectious. That of the peach can be carried to the plum, cherry, and apricot, and can be inoculated into the wild plum. It is believed that aphids may be responsible for its spreading. Indications are that resistance to this disease is transmitted to susceptible hosts when these are grafted upon resistant species.

Mosaic of potatoes.

Studies on potato mosaic at the Louisiana station show that this may reduce the yield from 80 to 95 per cent. Some Canadian strains, especially Spaulding's Rose, are quite resistant. Of five commercial strains, however, only one was good. Smith's strain of Triumph has yielded as high as 200 bushels to the acre. At the Maine station the disease was transmitted by juice inoculation, but only to a slight extent by contact of plants. It was found to be much easier to transmit it by plant lice and artificial mutilation than by contact of diseased plants or by flea beetles. In its control, roguing was found to be partly effective, if early, frequent, and complete, and early harvesting was quite so. Imported stocks were found to be good if from hill-selected or rogued stock from aphid-free regions or from healthy isolated fields. The principal agent in the transmission of the disease appears to be the pink and green aphis, the primary host of which is found to be the rose, and it is believed that a partial control of the disease, at least, may be secured by eliminating this host. It is therefore recommended that rose bushes in the vicinity of commercial potato fields, especially where certified stock is grown, should be removed or annually deaphidized. The disease was found in all commercial varieties in the State except Irish Cobbler. Varieties

were found to vary in resistance from none to nearly entire. Control by spraying was found to be difficult and expensive. Curly dwarf in Rural New Yorker was found to be due to a virus that produces mosaic when transferred to Green Mountain. "Streak" was found to be similar or related to mosaic.

Other potato diseases.

At the Nebraska station relative humidity is found to play an important rôle in determining the progress of tuber rots, there being a gradual increase in the amount of rotting corresponding to an increase in relative humidity. The North Dakota station reports that not all discolorations of the vascular ring are due to fungi. The common cause of wilt in the State is *Fusarium oxysporium* var. *longius*, and the chief cause of dry rot is *F. discolor* var. *sulphureum*, which gains entrance through wounds and follows the attack of wilt. Tests at the Oregon station show that the planting of a nonsusceptible crop in diseased soil for only one year is not sufficient to free the soil of Verticillium wilt.

In studies of potato wart, at the Pennsylvania station, a number of untested American varieties were found to be immune. Immunity appears to be an inherited character and can be imparted by either parent. In treating potato seed for black scurf, at the Iowa station, hot formaldehyde was found to be as effective for control as either mercuric chlorid or cold formaldehyle, and the rapidity of treatment by this method makes it available for large quantities of seed. By using formaldehyde of double strength and increasing the temperature, a treatment of two minutes instead of several hours was found to be sufficient and resulted in no injury to the seed.

At the Maine station leaf roll, net necrosis, and spindling sprout were found to be very commonly associated, as if caused by the same agency. Studies on the leaf roll at the station show that it can be transmitted both by grafts and plant lice, but inoculation of the juice did not transmit it. For its control, hill selection and roguing, which should be done a little later than for mosaic, were partly effective.

Investigations by the Idaho station on the calico disease of potatoes show this to be carried in the seed and apparently not to be infectious. It reduces the yield about 20 per cent. The causal organism of "streak" or russet dwarf disease was not isolated, and it is believed it may be a type of mosaic. It is transmitted in the field from plant to plant and infection has been secured by rubbing the juice of infected plants on the stalks of healthy plants.

From studies at the Vermont station it is believed that tip burn of potatoes may manifest itself as a physiological disease, due to loss of water from the hydathode pores and the consequent death of the marginal vein running under these. The hydathodes are grouped around the tip of the leaf where the disease first shows itself. At the Iowa station the physical character of the soil, moisture conditions, and shading are all found to be negative factors. The young hoppers are most injurious, the adults doing but little injury. The burning action is believed to be due to a toxin.

Several strains of potato Rhizoctonia have been isolated at the Utah station, which vary in their pathogenicity on different hosts. Some which appear identical in cultures vary widely in their ability

to infect host plants. Treatment of the tubers with corrosive sublimate decreased the amount of disease and increased yields. The Montana station finds that blackleg is largely a question of soil moisture, and where irrigation is held down the tubers remain sound and there is very little soft rot. It was not found to hold over in the soil.

At the Texas station, in spraying potatoes with Bordeaux mixture for late blight and scab, reducing the pressure from 180 pounds to 90 pounds per square inch reduced the protection one-half. Three nozzles per row gave much better protection than two nozzles. Bordeaux, 4–4–50, was the most efficient formula. This station also states that an organism has been persistently isolated from the storage rot of Irish potatoes that resembles *Fusarium oxysporium*, which may be a new species or a variety of the organism.

Tests at the Mississippi station on sweet potato black rot show that by bedding a rotten tuber infection practically always results, even in uninfected soil, indicating that all rotten material should be thrown out when bedding.

Fusarium wilt of potatoes has been investigated at the Nebraska station. This disease shows a difference in symptoms under dry land and irrigated conditions, the progress of the disease being much more rapid in the presence of high soil temperatures and moisture. There was practically no infection below 24° C. There appear to be three different types of infection, one coming from the seed piece, another from the stem and roots, and a third from the soil through the seed piece, the latter being the most common in irrigated sections.

In general, seed treatment at the Arkansas station for the control of potato scab was not found profitable for that State, due to the general acidity of the soils.

Sugar-beet diseases.

At the Utah station the dry-rot canker of sugar beets was found to be caused by a strain of *Corticium vagum* of the potato. Its effect on the sugar beet is severe, causing a dry rot and a damping-off of the seedlings. It does not appear to be seed borne. Late blight and root rot are also serious troubles, destroying all the foliage and the tap root of the affected beet succumbing to a black rot. The exact cause has not been clearly established; but a number of fungi have been associated with the destruction of the rootlets, which is the beginning of the disease, including *Phoma betæ*, *C. vagum*, *Pythium debaryanum*, and various Fusaria, but the decay of the tap root seems to be due to *Phoma betæ*. It is intimately associated with climatic fluctuations and is intensified by conditions which tend to lessen the vitality of the beet.

The Colorado station reports that the early stages of the rot of steckling sugar beets show as an internal rotting, from which various organisms have been obtained, all of which will cause the disease. When the beets attain considerable size and maturity they appear to be immune. Stecklings are low in sugar and very susceptible to disease. Late plantings and early harvesting tend to reduce the disease.

At the California station it has been demontsrated that the leaf hopper is not a mechanical transmitter of curly top of the sugar

beet, but that an incubation period of about five hours in the body of the insect is necessary before the disease can be transmitted. A combined incubation period of two days in the leaf hopper and the beet is required, after which the disease shows itself in the beet in about five days. No disease was produced when either single insects or masses were fed for five minutes on diseased beets and then immediately transferred to sound beets. All attempts to transfer the disease by mechanical means, such as transfer of juices, contact of diseased material, or through soil infection, failed. Where there is an average of four or five hoppers to the beet the crop is almost certain to be a total failure. There is no evidence that it is a seed-borne disease. The leaf hopper overwinters in the red-stemmed Alfilaria in the foothills of the lower part of the San Joaquin Valley, from whence it migrates northward as the season advances. Strong nicotin dust has been found to destroy the hoppers, but earliness and timeliness of application are important factors in its control.

Tobacco diseases.

Tests at the Virginia station of the disinfection of tobacco seed for angular leaf spot show that this can be accomplished by treatment with 2 per cent formaldehyde or with a 1:1,000 mercury bichlorid solution for 15 minutes, although this injures the seed slightly and delays germination a little. On untreated plats there was 25 per cent infection, the treated plats being entirely free. It may be carried over in the cloth cover of the seed beds and also in the soil. Boiling the cloth covers for 10 minutes gives complete disinfection, and if tobacco is fall plowed the carrying over in the soil is not so great. The Kentucky station finds indications that both this disease and wildfire are seed borne, and may be partially controlled by bagging the seed heads to prevent seed-pod infection. Wildfire is found by the Wisconsin station to develop most markedly between 82° and 91° F., although it could infect its host at a temperature as low as 59° F. and as high as 98° F. A relatively cold soil favors the disease and a warm soil reduces it.

At the Massachusetts station successful inoculations have been made of the wildfire organism (*Bacterium tabacum*) on the petunia and tomato, indicating that these plants may be possible hosts. For its control, the station recommends sterilization of the soil of the seed beds, seed disinfection with formaldehyde, and sterilization of the cloth covers used on the seed beds. Lime sulphur and sulphur dust did not give very good control, better results being obtained with fresh Bordeaux mixture, either as dust or spray.

The Connecticut State station emphasizes the fact that soil sterilization alone is not sufficient. If the disease appears in the field, control measures must be carried out early, best by the destruction of infected plants and removal of all infected leaves. Spraying is not believed to be practicable in the field and may injure the quality of the leaves.

The North Carolina station reports that infection of "speck" of tobacco comes through the seed and soil. It is recommended to use new cloth for covering each year, and to use disease-free seed.

Wheat rusts.

Studies at the Indiana station have shown that there are at least six biologic forms of rust in wheat. The cereal leaf rust is believed

to be an introduced disease, but closely related to wild-grass rust. It is probably carried over in the cereal and does not require an alternate host. The Minnesota station finds at least 33 distinct forms of stem rust of wheat which can be distinguished from one another by their action on different varieties. It is believed that the spores may be wind-borne and travel hundreds of miles. Spores were collected in spore traps with an airplane at an elevation of 1,650 feet. Urediniospores do not commonly live during the winter and the rust comes largely from infected barberries. The fact that these spores do not live over winter is confirmed by the Nebraska station. Orange leaf rust, however, was found on a number of cereals throughout the winter. The Montana station reports that that State has the most complete eradication of barberry of any State, and no stem rust appeared the past year, although leaf and glume rust was present.

Smut in wheat.

At the Washington station a count of smut spores on the seed of numerous samples of wheat from various sources showed a variation from 0 to 20,176 per grain. In the crops grown from these samples, the maximum percentage of smut was 20, while a considerable number of plantings remained smut free, even though the spore counts per seed were high. Numerous samples showing from 100 to 500 spores per grain remained smut free, indicating that a large percentage of the smut on the seed had lost its infective power; and the conclusion is reached that such resistant varieties as Marquis, when seeded in the spring, will rarely have sufficient smut to justify the expense of seed treatment. In a series of tests with artifical infection of the seed, varying from a few hundred spores per grain to a maximum of 278,000, the percentage of smutting in the crop was generally higher than in similar degrees of smutting of farm infected samples. As a result, it is possible to predict from microscopic analysis the probable percentage of smut which will appear in spring seedings, when disinfection is omitted, and to indicate when disinfection may be omitted. From a test of various seed treatments, the conclusion is reached that copper carbonate dust, at the rate of 2 ounces per bushel of seed, is as effective as any other treatment, including formaldehyde or bluestone, is more convenient to use, and is less injurious to the seed.

The California station also reports that very good success has resulted from treatment with dry copper sulphate or carbonate, the latter being slightly better.

The Idaho station found a relationship between the soil moisture from the time of seeding until the plants appeared above ground and the amount of infection with bunt upon the crop at harvesting time. The amount of bunt infection increased as the amount of moisture increased, and the highest infection developed at the lowest temperatures. Experiments showed that the infection can not live in soils that are continuously wet and that cultivation has an effect in reducing the amount of infection.

Wheat scab.

Studies at the Missouri station on the tolerance to acid conditions of the organism causing wheat scab (*Gibberella saubinetii*) show

that it has a wide range of tolerance of H-ion concentrations, and that conidial production markedly increases as the H-ion concentration increases.

The Wisconsin station found in investigations on the influence of climate on wheat scab, that wheats blight most in a comparatively warm soil, above 53° F., while corn blights most in a cool soil, below 68° F. Wheat and corn seedlings are attacked by the parasite only when under unfavorable environmental conditions as to temperature, moisture, soil reaction, or otherwise, or a combination of these factors. These results emphasize the value and explain the reason for planting spring wheat at the earliest safe date in the spring, winter wheat at the latest safe date in the fall, and corn only after the soil has warmed up in the spring. The station has been quite successful in selecting and breeding strains resistant to scab, based on individuals showing a marked freedom from "open" anthers.

The North Dakota station reports that there appear to be two phases of scab, a seedling blight and a head blight. In the seedling form (Fusarium) the fungus is rarely found above the first node above the diseased roots, and the organism does not travel up the stem. In the head form (scab) it only goes about an inch below the glumes. The embryo is attacked before the endosperm. It was found that formaldehyde treatment does not fully reach the inside of plump grains. Hot-water treatment was an effective means of control, reducing the disease to less than 1 per cent. The disease is much like Helminthosporium, and is not systemic.

Other cereal diseases.

The Tennessee station reported the appearance of downy mildew of wheat in the State for the first time. Studies on the foot rot of wheat, at the Washington station, have as yet not resulted in the isolation of the casual organism. The disease was first found in the State in 1919 and was severe in at least 40 per cent of the winter wheat in the Spokane Valley, often necessitating cutting the crop for hay and frequently reducing the yield from 30 to 50 per cent.

At the Minnesota station it was found that sandy soils and high moisture content are favorable factors for the development of Helminthosporium on wheat and barley. Investigations at the Tennessee station show that the external infection of wheat seed is heavy, mainly with a Helminthosporium or an Alternaria, or both, and very commonly with a wheat scab fungus, a Fusarium. Internally the seed was contaminated only to a slight extent, mostly with the scab fungus. Loose smut was perfectly controlled by the hot-water treatment, but not by formaldehyde. No treatment had any noticeable effect on wheat-root rot. The treatments apparently had no effect on the yield. Scab fungi were also often present in the root system of young seedlings, the damping-off fungus, Pythium, being of common occurrence. All of the above organisms cause root rot, and wheat deterioration is due to these as well as to scab and leaf and stem rusts.

The Iowa station has shown that the European buckthorn (*Rhamnus cathartica*) is the only alternate host of the crown rust of oats in Iowa, and aids the spread of crown rust very materially early in the season. The loss can be eliminated by eradication of the alternate host.

The Washington station finds resistance to oat smut to be heritable and in general to follow Mendel's law, although it is made up of multiple factors. Resistance appears to be dominant in oats and susceptibility dominant in wheat.

The California station has found a leaf scald of barley, due to *Rhynchosporium* sp., to be rather prevalent, especially on early barley.

Bean diseases.

Studies of bean rust at the Virginia station indicate that marrow and red or red mottled beans are most resistant, while most white beans and those of pea shape are susceptible. Two biologic strains of the causal organism were found, one on kidney beans and one on black-eyed cowpeas, either of which does not attack the other host. The Minnesota station has isolated at least two biologic forms of the fungus of bean anthracnose. The Michigan station finds that the organism causing bean mosaic is filterable and is apparently disseminated by insects. The use of 2-year-old seed proved an efficient remedy for the control of bacterial disease of beans.

Diseases of peas.

The Maryland station isolated several organisms from the root rot of peas, among them species of Fusarium, Ascochyta, and several bacteria. Tests of resistant varieties promise means of control, and the Delaware station emphasizes the benefits of rotation for this purpose. The Utah station has also found a number of organisms, including *Corticium vagum*, Pythium, and various species of Fusaria, and reports that it also occurs in the sweet pea.

Cabbage club root.

The Wisconsin station finds that club root of cabbage develops through a wide range of temperature, but that it is checked when the moisture is held at a point below one-half the water-holding capacity of the soil. Avoidance of poorly drained land for cabbage culture is therefore important in controlling the disease. At the Rhode Island station club root did not appear until the fourth year on heavily limed plats (10,500 pounds per acre), and was then much less than on the unlimed plats. Among the improved varieties of cabbage at the Iowa station, Iowa No. 5 has proved to be resistant to yellows and of a good typical Copenhagen type.

Tomato diseases.

Studies on the Fusarium wilt of tomatoes at the Georgia station have included tests for immunity of many cultivated and wild varieties, but without success, immunity being only relative. There is apparently no real immunity. The Louisiana station reports that the wilt of tomatoes, caused by *Fusarium lycopersici*, is a southern and warm climate disease, growing best at 29° C. Selections for resistance are quite promising.

The Tennessee station finds indications of three distinct strains of *Fusarium* of the section *elegans* among the tomato-wilt fungi. At the Texas station it was found that *F. lycopersici* is carried in every part of the plant, roots, stems, petioles, leaves, calyx, and fruit.

Cultures made from tomato plants, affected with blight, at the Washington station, showed in many cases both Rhizoctonia and

Fusaria, which indicate that there may be a relation between these two fungi in the production of the disease. At the West Virginia station it was found that the potato Phytophthora can be cultivated on tomato fruit, and then inoculated into the tomato plant without apparently increasing in virulence. Good results have been obtained in the control of late blight and also of leaf spot by spraying with Bordeaux.

At the Indiana station infections from the bacterial leaf spot of the tomato have been made on the pepper and potato and also on buffalo bur, bittersweet, matrimony vine, henbane, and wild tobacco. The causal organism has survived 16 months' drying on tomato seed and appears to live over winter in the field in the trash from diseased plants. This station obtained no evidence of seed transmission of tomato mosaic. Many weeds have been found to be hosts, especially the horse nettle and the clammy, smooth, and Virginia ground cherry.

The Tennessee station finds tomato buckeye to be widely distributed over the State, and that the same organism, a Phytophthora, causes a rot on rhubarb. Spraying with Bordeaux mixture readily controlled Cercospora and Alternaria leaf spots, and had no effect on the early ripening of the fruit. Fusarium wilt appeared to be carried by the seed.

Other vegetable diseases.

The Massachusetts station finds that carrot blight is not a bacterial disease but is due to a fungus, Macrosporium. Eggplant blight studies at the Louisiana station show this to be caused by *Phomopsis vexans*. It reduces the yield in the State fully one-half. It is carried over winter in and on the seed, and seed and soil treatment, with spraying with fungicides, when properly done, will check it, but it is questionable whether this would be practicable. It has not been possible to secure disease-free seed.

Downy mildew of lettuce is found by the Iowa station to occur on both wild and cultivated plants. Wild lettuce is often a source of infection. It is primarily a seedling disease, and Bordeaux mixture gives efficient control if applied at this stage. The Texas station reports that tip burn of lettuce, which is very destructive, is apparently a bacterial disease. An organism has been isolated that resembles one described by the Kansas station. The Massachusetts station finds that lettuce drop is fully controlled by formaldehyde.

Tests at the Oregon station showed very effective protection of seedlings from onion smut by the formaldehyde drip method, when the solution is applied in proper strength and quantity. The Wisconsin station reports that the progress of this disease is facilitated by a cool soil (60° F.), and at temperatures of 84° F. or above it is completely prevented.

The Georgia station finds a number of organisms in the fruit rots of peppers, including several species of Colletotrichum, Glœosporium, Macrosporium, Cytospora, and an unidentified bacterium. The New Mexico station reports that the recommendations to keep the soil moisture not higher than 12 per cent by irrigation, and to use light loamy soils with good drainage is being successfully adopted for the control of chile blight. A strain, Variety 9, has

proved very resistant, and by planting this in connection with proper soil moisture conditions almost complete control is secured.

At the Pennsylvania station two distinct species of Phytophthora, including several strains, were found to be associated with the crown rot of rhubarb.

At the Michigan station, passing Fusaria through the tomato was found to weaken it and rob it of its power to digest starch.

Pink sauerkraut, which was giving considerable trouble in Wisconsin, was found by that station to be due to the growth of certain yeasts, and was dependent upon the amount of salt used, the amount of acid, the temperature, and the oxygen supply.

Studies at the Texas station showed that stem-end rot of watermelons is due to *Diplodia tubericola*, which causes the Java black rot of sweet potatoes, and can be readily carried from one host to the other; therefore, the two crops should not follow one another, as is often done in Texas. The station also found that watermelon anthracnose is caused by *Colletotrichum lagenarium*, and that this organism also readily infects cucumbers, cantaloupes, squashes, gourds, and citron.

Forest diseases.

The Minnesota station reports that the removal of all currant and gooseberry bushes within 200 to 300 yards will protect pines from the white pine blister rust under usual conditions. At the Utah station a severe disease of the poplar (*Populus bolleana*) was found to be due to a Cytospora. This especially affects trees headed back or severely pruned, so that it is thought that this practice must be abandoned. American varieties of sycamore were found to be very susceptible to a disease of the leaves and twigs, due to *Gnomonia veneta*. European varieties are more or less resistant. The Arizona station reports a disease of the pepper tree, due to a species of Trametes, which produces swellings and knots on the trunk and branches and a rather soft rot of the wood. This is found to spread quickly through the trunk and requires careful attention to pruning and the protection of wounds.

Miscellaneous plant diseases.

Studies at the Montana station show that sunflower wilt is apparently due to a Sclerotina that causes damping-off and occurs mostly on land that has been in wheat. The North Carolina station has found a new bacterial disease of the soy bean, caused by an unidentified species of Phoma, which lives over winter and affects the pods and stem.

The Arkansas station is studying a bacterial disease of foxgrass. Inoculation experiments show that the organism is capable of infecting all common cereals except rice.

The New York State station has found a new species of fungus, *Septoria callistephi*, causing a leaf blight of the aster.

In a plant disease survey of the State, made by the Arkansas station, three new diseases were found, a Septoria glume blotch of wheat, a Phoma disease of cotton, and a Phoma on plums. The glume disease has been reported in Europe.

Seed treatment.

In studies of the action of formaldehyde on tobacco seedlings at the Massachusetts station, solutions of 1:1,000, which is the

strength usually used in watering the plants in transplanting, were found to be toxic, although in the greenhouse no toxic effect was noted with a strength of 1:750. No concentration has yet been found that will affect Thielavia without injuring the plant.

In treating wheat seed with formaldehyde the Oregon station found that the formaldehyde was absorbed by the grain and apparently retarded enzym activity as well as checked the respiratory processes. It has a retarding effect on germination and a spindling effect on seedlings, but its action varies with temperature, barometric pressure, etc.

ENTOMOLOGY AND ZOOLOGY.

Bees.

At the Minnesota station it was found that bees can be successfully pedigreed. Mating usually occurs between 2 and 5 p. m., and by keeping the bees in the dark for 5 days and bringing them out about 5 p. m., selected matings can be secured. Studies of the habits of bees, at the Iowa station, have brought out some interesting facts. A bee starting to gather honey from one particular kind of flower will ignore all others, and if the honey flow stops in that kind of flower it goes out no more for the day. Only in exceptional cases were nectar carriers found to change, even temporarily, to carrying pollen upon the cessation of the nectar flow for the remainder of the day, except in the case of those gathering nectar and pollen from the same plant. They were found to carry from 50 to 75 to 85 per cent of their own weight of pollen and as many as 30 trips may be made in a day. The time required for a trip for nectar varied with the abundance of the flow, from 15 minutes to 1 hour. Trips for pollen were often completed in five minutes. The usual interval spent in the hive between trips was three minutes. On an average a bee flies at the rate of about 10 miles an hour when going to the field and 15 miles an hour when returning to the hive, but can fly at the rate of 20 miles an hour with a load in a calm. They were frequently noted as traveling about a mile in three minutes unloaded and in four minutes loaded, if the wind was not blowing.

At the Kansas station bee colonies protected by a windbreak wintered much better than unprotected ones and the two-story hive gave much better results than the one story. Bees need protection even more during an open winter than during a severe one. At the South Carolina station dry sawdust packing proved an excellent winter protection, using 4-inch layers at the sides and 6 inches on top.

The Oklahoma station reports that annual sweet clover has proved to be superior as a honey plant to the biennial varieties, as the flow can be prolonged by early and late plantings. In studies at the Washington station on the poisoning of bees in orchards that have been sprayed, especially where alfalfa is grown, an attempt has been made to incorporate a repellent in the spray. Nicotin, naphthalene, and lime-sulphur proved quite effective. The loss which often results from spraying is a serious one to the orchardist as well as the beekeeper, as it interferes with the natural pollination.

Fruit insects.

The New York State station finds that the apple red bug is susceptible to dusting mixtures containing 1 or 2 per cent of nicotin.

At the Ohio station the use of miscible oil at the time of dormant spraying is found to be efficient for the control of the red spider in apple orchards.

The Oregon station reports that a combination of lime sulphur, 1 to 12, with 2–100 oil is very efficient in controlling the pear-leaf blister mite, and the pear thrips was effectively controlled by spraying with miscible oils or whale-oil soap and nicotin sulphate at the New York State station. Experiments at this station confirm early indications that the pear sinuate borer is susceptible to treatments with arsenical poisons.

Lead arsenate in the "pink" spray was efficient in controlling fruit worms of the pear at the Oregon station.

For the control of the apple and peach tree borer, experiments at the West Virginia station show that spring and fall applications of miscible oils, scraping the soil from around the trunk, applying the remedy, and replacing the soil, gives the best results, being 90 per cent efficient. Paradichlor-benzol may be used, but there is a little more danger to the tree. Both the Missouri and New Jersey stations report excellent results from the use of paradichlor-benzol, the latter station showing that this will kill 95 per cent of the borers in trees 6 years old or older in fall treatments, with no injury to the tree. The Maryland station finds, however, that this material severely injures young trees. Pine tar creosote did not cause injury to young trees, and if applied with proper reference to the time of egg laying is quite effective.

The New York State station reports that at least three species of plant bugs breeding on hickory and oak are causal agents of serious deformations of peaches.

Studies made at the Florida station on plant bugs and their injuries to citrus and other trees, as well as to truck crops, show that tobacco and sunflowers are favorite hosts, which suggests a method of control by planting these as trap crops.

At the Kentucky station three species of destructive leafhoppers have been found upon the grape, which cause a mottling of the leaf and are very destructive. They produce two broods a year. The Iowa station reports that by the removal of pruning rubbish from vineyards the grape cane borer can be almost entirely eliminated.

For the control of leaf rollers on the apple and pear the Oregon station recommends miscible oil, lime, and glue as an efficient mixture to kill the eggs. This is confirmed by results at the Montana station, which reports that many orchards were saved by its use. The Washington station finds that these insects are remarkably resistant to standard sprays.

Strawberry insects.

Observations at the Tennessee station indicate that the strawberry weevil works on several unrecorded food plants of economic importance. It is found to cut the buds of the apple and breed in them. The newly emerged weevils also cut the buds of tomato and cotton but do not breed in them. A mixture of 85 parts of sulphur and 15 of lead arsenate is recommended for its control. In the South it attacks new beds mainly, while in the North it is most injurious in

old beds. At the Arkansas station this weevil is found to lay eggs also on the blackberry, dewberry, and raspberry. The strawberry variety Aroma was found to be quite immune to its attacks. The Tennessee station finds the strawberry crown borer to be very destructive, preventing the formation of runners. The eggs are laid the latter part of March and plantings before April 1 from selected plants, free from the borer, are quite safe if at least 25 rods away from old plantings, since the insect can not fly, which simplifies its control. Old beds should be plowed under. Studies of the strawberry root louse show that egg laying begins November 17 and continues to January 1, hatching about the middle of February. It has not yet done serious injury.

Codling moth.

Codling moth studies at the Massachusetts station show that 100 per cent of the early larvæ pupate at once and produce a summer generation, those coming later make cocoons and winter over. At the California station this insect was found to attack the walnut as well as the apple and to be readily transferred from one to the other. Spraying or dusting with lead arsenate gave as good results on the walnut as on the apple. At the Missouri station the largest percentage of clean fruit was obtained by using 100 pounds pressure and the disk and Bordeaux nozzles, and the smallest percentage with the spray given with 250 pounds pressure. Moderate pressures have consistently given higher results than high pressures. More worms entered at the side of the fruit than at the stem or calyx ends.

At the New Mexico station there are believed to be four full broods of the codling moth in that State. Late spraying is believed to be essential there, as 75 per cent of the infestations occur through the side of the fruit. The so-called calyx spray is less important, the second and third broods being the most important and these usually come after July 1. In the pear spraying schedule, the calyx and first brood spray can be combined, reducing the expense without decreasing the efficiency.

At the Washington station calcium arsenate was inferior to lead arsenate and magnesium arsenate was still less efficient in controlling the codling moth. Rod and clipper nozzles gave better results than the spray gun. The use of laundry soap as a spreader was not of much advantage.

San José scale.

Reports from the Washington station show that the San José scale responds to the usual insecticides very differently in different localities, and that the actual strength of spray is not the only factor involved. Dry polysulphids were not as efficient as the ordinary liquid lime sulphur. Oil sprays were more rapid in action than sulphid sprays. At the Texas station commercial sulphur products as dormant sprays were very successful for the control of this insect. Successful control on nursery stock was secured at the Missouri station by dipping in a solution of miscible oil of a strength of 1 gallon of oil to 12 to 15 of water, this treatment killing 99 to 100 per cent of the scales.

Mexican bean beetle.

Extensive studies on the life history of the Mexican bean beetle, at the Alabama station, show this to be somewhat different in the South from what it is in its western habitat. Emergence from hibernation begins early in March and the first eggs are deposited about March 21. In Alabama it is found to be active, in some degree, during every month in the year. Breeding begins in March and a complete generation is produced before the beetle is supposed to emerge from hibernation in the West. Development is also more rapid, a record of 28 days from egg deposition to the adult stage having been obtained, and reproduction continued steadily until all food supply was destroyed by frost, resulting in probably four or five generations. The food habits also appear to be undergoing a readjustment, as it attacks cowpeas, which it had not previously touched in the West, as well as soy beans and all varieties of table beans, navy beans being particularly susceptible. There is evidence of very extensive early dispersal of hibernating adults, amounting to more than 75 miles in some cases. Only one parasite has been found, which is rare, and birds do not touch the beetle.

The New Mexico station reports that in the southern part of the State the broods so overlap that distinctions can not be made. This year they were noted as early as May 28 in Torrance County and May 15 in Dona Ana County. They are found to lay eggs on six or seven different varieties of weeds, not necessarily legumes. Active adults and pupating larvæ were taken as late as September 28 in the Mesilla Valley. The Colorado station reports good results in the control of this insect with arsenite of zinc, this giving better results than arsenate of lead. A single spraying controlled the insect fairly well in that State and did little injury to the foliage.

Corn ear worm.

Studies on the corn ear worm at the West Virginia station show that the first brood is small and scattering. The second one is larger and more regular and is responsible for most of the injury to early sweet corn and tomatoes. The third brood is large and more coherent than the earlier broods, and is not sharply distinguished from the fourth brood which appears late in September and is apparently incomplete and is wanting in some years. There is much overlapping of broods. The third brood feeds on the late sweet corn and field corn. It is most abundant for 10 to 14 days from about August 22 to September 7. Silage corn planted to mature and harvest by the middle of September suffers less than if planted later. In control by dusting, the dust must be placed on the silk to be efficient. Spraying with lead arsenate and tobacco extract was found to kill the eggs. In a comparison of dusting and spraying, the latter gave 25 to 30 per cent better control, cost less, and was easier to apply. At the Missouri station on a plat sprayed with lead arsenate there was 4.77 per cent damage, on one dusted with lead arsenate 9.88 per cent, and on check plats with no treatment 12.2 per cent.

Corn root worm.

Tests at the Louisiana station of planting date to escape the southern corn root or budworm resulted in the March planting being badly infested, but in no injury to the April and May plantings. All methods of seed treatment were ineffective.

Cotton boll weevil.

In hibernation studies at the South Carolina station of 1,000 weevils placed in cages 12 per cent hibernated successfully and came out alive in the spring, the majority coming out during April, and all were out by June 1. The Georgia station reports that dusting with calcium arsenate just about paid for the cost of treatment.

The Alabama station has studied weather conditions as affecting weevil injury. If sufficiently hot and dry for a period of more than a month, especially during the first part of the fruiting season, the weevils may be naturally controlled so fully that dusting will not be needed or will not pay. While it may appear to be inadvisable to dust in periods of frequent rains, it is believed that every effort should be made to continue dusting at the usual four or five day intervals, in spite of threatening weather, as there is no natural control at such times and the weevils multiply with great rapidity. As the margin of profit per acre decreases there must be a prospect of higher yield to justify dusting. In tests made at the station the profit from dusting in most cases increased rapidly as the margin of yield increased above half a bale per acre.

The Texas station reports an increase of fully 30 per cent of the cotton crop when lead arsenate was properly applied for the control of the boll weevil. At the Mississippi station parasites of this insect were found to vary much in different localities, from none to 50 per cent. Calcium arsenate, both as dust and spray as well as mixed with molasses and applied by hand, when properly applied, controlled the weevils to such an extent that paying results were obtained when cotton was grown on land fertile enough to make a half bale or more to the acre without weevil damage. It was found that the pink boll worm is readily killed at a temperature of 125 to 130° F., and cotton seed will stand temperatures of 175 to 180° F. for several hours.

Thurberia boll worm.

At the Arizona station it was found that the larvæ of the Thurberia boll worm will feed on tame cotton, but it has been impossible to get eggs deposited on that plant. The life history of *Thurberiphaga catalina* has been worked out and it has been found that the larvæ will complete their development on cultivated cotton.

Leafhoppers and tipburn.

At the West Virginia station quantitative tests of infection of potatoes with tipburn by leafhoppers indicate that this may be accomplished by a single hopper. It is believed the trouble may also be due to other causes. Excellent results in control were obtained at the Iowa station by spraying three times with Bordeaux mixture. Tests showed that it is the toxicity of the Bordeaux mixture to the nymphs and its repellent action on the adults that affords effective protection. It was found that Bordeaux mixture does not prevent tipburn by its action on the leaf, but rather by its action on the insect. At the Wisconsin station spraying with Bordeaux mixture upon both top and under side of the leaves controlled the leafhopper and the following tipburn. Unmistakable symptoms of hopperburn were found in a muskmelon field, and a large number of adults and nymphs of the hopper were found on the leaves, indicating that this is apparently also a host plant.

Tobacco insects.

Studies of the tobacco flea beetle at the North Carolina station show that a strip 18 inches wide around the seed beds will keep the insect out. Dusting with lead arsenate has been successful and is claimed to have saved from $25 to $30 per acre. At the Wisconsin station the northern tobacco worm was effectually controlled by a dust application of one part of lead arsenate with eight parts of air-slaked lime, or a spray of 2 pounds of lead arsenate to 50 gallons of water.

Cabbage maggot.

The New York State station finds that corrosive sublimate of standard dilutions is destructive to the eggs and young larvæ of the cabbage maggot and will not hurt plants with a well-established root system. Similar studies at the Indiana station also showed the effectiveness of this material, used in two applications, 1 ounce to 10 gallons of water, or a 1 per cent dust mixture of the sublimate with gypsum or hydrated lime. One treatment with the liquid was effective in controlling the maggot on the radish. Tests at the New Hampshire station showed a marked efficiency of a tobacco dust and lime mixture, composed of equal parts of each. This is found to have a direct insecticidal effect upon the egg. On treated plants the larvæ did not reach the roots for several days after the untreated ones, which is a distinct advantage to the plant. Egg laying on the treated plants was very much reduced, but rains removed the protection.

Grasshoppers and crickets.

Studies in grasshopper control by the Montana station show that these insects feed mainly from 8 to 11 a. m., and poisoned bait should be put out at this time. A bait composed of bran, molasses, white arsenic, and salt, with or without amyl acetate, gave practically a clean-up. The wet method of mixing the bait was found preferable, there being less poisoning and irritation of the worker's arms. The Wisconsin station also reports the above mixture far superior to all others.

At the South Dakota station crickets were found to cast their skins from 9 to 11 times. Ordinarily there is only one brood a year, but some years there may be two matings. Nearly 50 per cent of the eggs were found to be parasitized, and a new parasite was reared. Crickets cause much injury to alfalfa, for the control of which disking in the fall or deep plowing is recommended.

Field and truck crop insects.

The Kansas station reports that the pea louse has been found on alfalfa, causing at times a loss of 25 per cent of the first crop. The clover-leaf weevil was also found to cause considerable damage to alfalfa. The Colorado station finds that arsenate sprays, if properly applied, will control the alfalfa weevil.

Studies on the cowpea weevil at the North Carolina station show that this insect appears to be changing its habits and is working more on the soy bean, which is replacing the cowpea as a crop in the State. The Oklahoma station finds that the cowpea louse winters on Euonymus and *Ilex decidua*. Paradichlorbenzene was efficient in controlling it.

The Missouri station finds that marked diminution in chinch-bug infestation has resulted from systematic cleaning up and burning of all waste. It is estimated that the loss caused by this insect in that State in 1920 was $15,000,000.

Tests at the Texas station show that fumigation of the tubers for the control of the sweet-potato weevil was not satisfactory, cultural methods being more promising.

Investigations at the Maine station show that the sole over-wintering host of the potato aphis *Macrosiphum solanifolii* is the wild rose, and the prevalence of this insect on potatoes in the Aroostook region depends directly upon the prevalence and proximity of the wild rose in the vicinity of the fields.

The Massachusetts station reports success in trapping the flies of the onion maggot, if this is done at the time of egg laying, the maggots being very much reduced by this means. The striped cucumber beetle was successfully controlled at the Indiana station with a dust mixture of one part of calcium arsenate to 20 parts of gypsum.

The Wisconsin station reports that the serious losses caused by the pea moth may be reduced from 25 per cent to 2 or 3 per cent by planting early varieties as early in the spring as the soil will permit and refraining from planting peas on or near the same field two years in succession. New plantings should be at least one-fourth mile away from the previous year's plantings.

Miscellaneous insects.

Several species of June beetles are found by the Kansas station to have a 1-year life cycle, instead of two or three years as previously reported. The Mississippi station finds that May beetles do considerable damage to pecan trees, and 20 species have been found on them, some being new to the State. The hickory-bark beetle is also a potential pecan insect.

The Maryland station secured satisfactory control of the boxwood leaf miner with nicotin solutions to which molasses was added. At the New Hampshire station tests of tobacco dust diluted with lime for the control of root maggots showed that dry applications killed the larvæ, while infusions were ineffective. Rain reduces the efficiency of the treatment. This mixture was found to be of value both as an insecticide and as a repellent.

The Utah station reports a new species of moth seriously attacking sagebrush, also a new species of parasite.

The pale western cutworm is reported by the Montana station as a very serious pest in that State. Methods of control have not been very successful, but a bait of poisoned fermenting molasses has considerably reduced its prevalence. It is estimated that last year it destroyed $5,000,000 worth of crops.

The Kentucky station finds two species of white fly attacking plants in the greenhouse. One, *Aleyrodes vaporariorum*, may produce a brood in about 20 days. It can produce young without mating, but in this case all are males. A second introduced species enters the greenhouse in the fall. The adults are readily killed with fumigants, but as the eggs are not affected several fumigations are necessary.

The chrysanthemum midge was effectively controlled at the Maryland station by early spring spraying with nicotin solutions about the time the slips are taken. Most of the injury is done during the cool weather of the spring and fall.

The Kentucky station reports that paradichlorbenzol is an excellent remedy for clothes moths, carpet beetles, ants, etc. The Mediterranean flour moth was successfully eliminated from mills by fumigating with hydrocyanic acid at the North Carolina station.

The Massachusetts station found the Indian-meal moth to be the cause of trouble in a candy factory, infesting the boxes of packed candy and being found after these were delivered to stores. The moth was brought in on nuts. It was completely controlled by fumigating the nuts and screening the packing rooms.

Tests at the Oklahoma station show the great vitality of the sticktight flea. One individual lived over two years and seven months and another over three years without feeding. The Oregon station finds that earwigs can be very effectively controlled with sodium fluorid with bran, molasses, and other carriers.

Moisture and temperature effect on insect life.

In studies on insect activity as affected by moisture and temperature, at the South Carolina station, it is found that the rate of metabolism is directly correlated with the convergence of the temperature and moisture, temperature being the dominant factor. From 58° to 90° F. are the temperature limits for metabolism, and from 40 to 68 per cent the moisture limits. Parasites are controlled by the same laws. The maximum control by parasites can therefore be quite accurately predicted from climatic conditions.

Parasites.

The Mississippi station has found two new parasites of the southern grass worm, which are very effective in its control, one being a bee fly and the other a disease known as "polyhedral disease." The North Carolina station finds that of the mountain pasture insects there are 10 or 12 species that are important, taking more from the pasture than does grazing. It is believed that grazing with sheep at the time the eggs are deposited may control them.

The South Dakota station finds that parasites control from 30 to 60 per cent of the wheat-stem maggot. Fall planting of trap crops and the fall destruction of wild hosts, volunteer rice, barley, etc., are recommended.

The New York Cornell station has reared and successfully introduced a newly discovered parasite of the woolly aphis. At the Texas station 54 generations of *Aphis gossypii* have been bred without the appearance of any males, indicating that asexual reproduction is the rule with this species.

Insecticides.

The West Virginia station has been engaged in a study of the possibility of insect control by impregnating the host plant with poison. In experiments on the wild apple, a strength of 1:1,000 potassium cyanid killed the tree, 1: 10,000 either killed or injured the tree severely, 1:25,000 did much injury, but 1:100,000 did no injury. The woolly aphis was killed by all strengths below 1:100,000, although there was an area around the roots where the

aphids were not killed. In experiments on the wild cherry, aphids were killed with 1:100,000 with some possible injury to the plant.

At the New Jersey station, 0.0002 gram per liter of hydrocyanic acid was found to give perfect control of greenhouse insects, at 40° to 100° F., in closed vessels. A dosage of $\frac{5}{8}$ ounce per 1,000 cubic feet gives a density of 0.0003 gram per liter.

In studies of the immunity of insects to insecticides at the Washington station no progressive immunity of the San José scale to oil sprays was noted, but there was a local partial immunity, fluctuating from year to year.

At the Ohio station an outbreak of the catalpa sphinx was successfuly controlled by dusting from an airplane, a hopper being attached to the side of the cockpit, and dry undiluted lead acetate used. The aviator flew close to the ground, the wind and current of the propeller disseminating the powder widely over a field of 6 acres. The grove was passed over several times, less than a minute being required, and it is estimated that 99 per cent of the caterpillars were killed.

The Oregon station finds that by the use of caseinate as a spreader, it is possible because of the more even spread to reduce the lead arsenate in sprays of this material one-half with equally good results.

Nematodes.

The Oregon station reports finding nematodes on alfalfa for the first time in this country, and that they were artificially transferred to clover. A method of testing for their presence has been devised by the Alabama station, which can be carried out in two weeks, based on growing summer squash which is very susceptible to them. By means of this test it can be determined how long it is necessary to fallow in order to eradicate the nematodes.

Crawfish.

Investigations at the Mississippi station showed a 98 per cent efficiency in the extermination of crawfish with carbon disulphid on small areas. Two poisonings were necessary. Tile drainage helps in control, and should be combined with poisoning. Three species have been studied, one probably new. These vary largely in their breeding habits, producing from 16 to 500 young, some requiring open water, while others do not.

ANIMAL NUTRITION.

Nutritive requirements.

At the Connecticut State station rats fed a ration in which fat is a minimal contamination quadrupled their weight in the usual time and appeared as well nourished as rats with a liberal amount of fat in their diets. It is assumed that pure fats are not an essential part of the maintenance diet. In a similar test with a diet containing only an exceedingly small amount of carbohydrates the rats grew from an early age to adult size at a rate rarely exceeded on normal rations. A chemical analysis of the bodies of these rats showed that they contained practically as much glycogen as rats fed a diet containing abundant carbohydrates, indicating that the rat can build its tissue carbohydrates from noncarbohydrate material and can get the necessary energy from other sources than carbohydrates.

At the Missouri station a biochemical study of the squab and mature pigeon in regard to protein storage showed the former to have a 75 per cent higher lipoid and a 15 per cent lower protein content than the latter. The lecithin content of the squab was greater and the total protein content about 10 per cent less soluble and contained relatively less albumin, globulin, amino acids, and extractive matter, but relatively more proteose, peptone, and peptid nitrogen. A determination of the maintenance requirements with different planes of nutrition showed this to vary. With a lot receiving a liberal ration, this was 5,777 therms daily per 1,000 pounds, with a more restricted ration 4,869 therms, and with a still lower ration 4,408 therms. Holstein heifers did better on the low plane than did Jerseys. There was little relation between the protein plane and growth in height, but a close relation with increase in weight.

The Illinois station finds that for maintenance there is not much difference between the vegetable proteins, but for growth the animal proteins are found to be of a materially higher value than those from vegetable sources. Tests at the New York Cornell station indicate that the protein of coconut oil meal has a higher growth producing value than that of corn meal, and lower than that of rice bran or wheat middlings.

Studies at the Kansas station confirm the fact that none of the short-chain fatty acids in the food are deposited in the body fat, but that the unsaturated fatty acids of the food are so deposited, thus causing the body fat to have a low melting point. The results also indicate that body fat produced by a high protein diet contains more of the unsaturated fatty acids and has a lower melting point than that produced by a low protein diet. In experiments at the Oklahoma station it was found that with a 6-months-old pig and a year-old pig, on the same feed, the fat of the older animal had a considerably higher melting point.

Experiments with swine at the Wisconsin station indicate that roughage may not be necessary for the health of these animals if the rations contain all the necessary nutrients and vitamins. Pigs fed grain alone with no roughage get stiff, but when this is supplemented with dirt or charcoal they give little indication of stiffness with the former, although more with the latter. A stiff pig weighing 250 pounds rapidly recovered and gained up to 350 pounds when cod-liver oil was given.

Nitrogen equilibrium could not be maintained with high-producing cows on a ration of clover hay and silage with corn, oats, and barley, but with alfalfa hay it could be maintained. Corn stover and timothy hay, grown on very acid soils, showed a very low lime content, indicating that if these were used as the only roughage with breeding animals they would produce bad results. Although there is some popular prejudice against the use of barley as the only grain for breeding cattle, entirely satisfactory results were obtained by its use.

Vitamins.

At the Connecticut State station rats fed a diet deficient in both fat and carbohydrates, consisting of 90 per cent protein and 5 per cent inorganic salts with a small daily dose of vitamins in dried alfalfa and brewery yeast, have grown at more than normal rate up to 225 grams weight, but subsequent growth has been much slower.

Trials with variable quantities of vitamin B in rations otherwise identical showed a quantitative relationship between the amount of vitamins fed and the gain in weight. Ophthalmia appeared only in rats deprived of the fat-soluble vitamin, but never in those weakened by other disease or defect of diet, showing it to be purely a food-deficiency disease and not infectious. Rats have been grown from early age to full adult size on dried whole milk powder, cornstarch, and lard, indicating that dried milk powder is not necessarily deficient in vitamins.

In extensive studies on vitamins made at the Wisconsin station, whole milk was found to be very rich in fat-soluble vitamin as compared with its content of water-soluble vitamin. Two cubic centimeters a day of whole milk was sufficient to produce normal growth in rats fed white corn, while it required 16 cubic centimeters per day to supply enough water-soluble vitamin for a rat to grow normally. There was no decrease in vitamin on heating milk under 15 pounds pressure at 120° C. for an hour. In centrifugal skim milk the amount of fat-soluble vitamin is only one-tenth or less of that in whole milk, and therefore the so-called "filled milk" (evaporated skim milk to which coconut oil has been added) is so deficient in fat-soluble vitamin that it would not sustain normal growth in rats even when liberal amounts were supplied. Results obtained at the Minnesota station do not support the theory of a chemical relationship between soluble vitamin and plant carotinoids.

In studies at this station on the distribution of antiscorbutic vitamin, it was found that 1 gram per day of green forage from oats, alfalfa, corn, or timothy will provide enough of this vitamin to protect a guinea pig from scurvy, while it takes 1½ grams of cabbage or 3 grams of rutabagas or turnips. Potatoes, being much lower in this vitamin, from 5 to 10 grams are needed. Ten grams of yellow carrots are required and 20 to 30 grams of sugar beets, sugar mangels, or table beets. Fat-soluble vitamin is found to be quite stable, as it can be boiled with quite dilute acids or alkalis or treated with hydrogen or oxygen in acid or alkaline solutions with little or no loss, but under certain conditions oxygen destroys it quite readily. It is also destroyed to some extent by the rays of the sun, from which, however, it is protected in plants by the chlorophyll. In hays, bleaching the chlorophyll by rain or over exposure to the weather results in a loss of the vitamin.

The antiscorbutic vitamin is much less stable than the fat-soluble vitamin. Certain types of fermentation destroy it; others do not. It is absent in silage and roots, and vegetables stored over winter are less potent in antiscorbutic properties in the spring than when fresh. It is soluble in water, alcohol, ether, chloroform, or acetone, and is destroyed by oxidation by hydrogen peroxid or potassium permanganate.

Four-weeks-old puppies fed a basal ration low in fat-soluble vitamin, consisting of rolled oats, white corn meal, skim milk, salt, and a little calcium phosphate, developed rickets in six to eight weeks, but with the addition of 5 grams of cod-liver oil they became normal in 10 days. One lot of poultry fed white corn and casein gave an egg production of 108 for the first month and 19 the second, with a loss of 80 per cent of the chickens. A second lot fed the same

ration with an addition of pork liver (rich in fat-soluble vitamin) laid 117 eggs the first month and 107 the second, with a loss of only 10 per cent of the chickens. The addition of cod-liver oil to the ration of the first lot brought it up equal to the second lot.

A definite relation is found between yellow coloring matter and fat-soluble vitamin content, yellow corn containing more than white, deeper colored butter fats more than light colored, and light colored beef fats less than higher colored. A similar condition is found in egg yolks produced under ordinary conditions, those richest in yellow color being richest in fat-soluble vitamin, but it is possible to produce a light colored yolk very rich in this vitamin by the use of pork-liver or cod-liver oil. As far as is now known, white corn is as good as yellow for horses, dairy cattle, beef cattle, and sheep if they are fed ordinary well-balanced rations, including plenty of good green-colored hay. This is not true for hogs.

It is found that dogs on a ration low in fat-soluble vitamin suffer from the same eye disease (Xerophthalmia) as rats.

The theory that there is a vitamin that controls or affects the ability of animals to assimilate and use the lime in their foods has received confirmation. Fresh green forages apparently contain this vitamin. There is still a possibility, however, whether this ability to increase lime assimilation may not be due to fat-soluble vitamin. Experiments show that a ration low in lime may be safely used as the only roughage for a part of the gestation period, but not during the last three of four months, when the most growth occurs in the fetus. Animals fed straw as a roughage all through pregnancy aborted or produced dead or weak offsprings. When cows were fed during the first seven months of gestation on clover hay and oat grain, and the hay was then replaced by oat straw, they produced normal calves, but if the substitution of the straw was made two months earlier the calves were premature, undersized, and died. This trouble was corrected by the addition of legume hay, which is rich in lime. Goats on a mixture of grains and oat straw gradually went into a negative calcium balance, but when put on pasture for 10 days again started to store calcium. Further tests along this line with goats showed that with the addition of cod-liver oil they quickly went into a positive calcium balance again.

In nutrition studies at the Minnesota station it was found that certain indol derivatives have antiscorbutic properties. The antiscorbutic properties of milk are destroyed quite readily by oxidation, while heat alone has little or no effect, even in an atmosphere of carbon dioxid. In the presence of oxidizing agents the antiscorbutic properties are destroyed slowly at room temperatures and the speed of oxidation is increased by heat. This was also found to be true of the antiscorbutic properties of orange juice. The antiscorbutic property of cows' milk fluctuates with the vitamin content of the food eaten by the cow. In the spring the milk is superior in nutritive and antiscorbutic properties to that produced during the winter months on dry feeds. Summer milk is better than spring milk. It is found that summer butter that has been stored for several months loses its fat-soluble vitamin rapidly upon exposure. Tests show that diets low in protein and water-soluble vitamin B cause atrophy of the testes and hypertrophy of the

adrenals, and when the vitamin is omitted the effect is more pronounced than when the percentage of protein is low.

At the New York State station the first noticeable effect in poultry in vitamin starvation (a polished rice diet) was a loss of appetite, the food consumption falling to a low amount. There was a continuous loss of weight and egg production ceased immediately. In from six to eight weeks active symptoms of polyneuritis appeared, resulting finally in more or less complete paralysis. In vitamin starvation the animal was unable to utilize in the normal manner a diet consisting of carbohydrates.

Experiments carried on at the Iowa station show that rabbits have a larger vitamin A requirement than rats or swine, indicating the possibility of further differences of omnivora and herbivora. At the Kansas station, eggs from hens receiving a vitamin-free diet when fed to rats greatly retarded their growth. The North Dakota station has secured some evidence that sprouted grain will prevent scurvy.

Experiments at the Wisconsin station show that chicks and pigeons require much more water-soluble vitamin than rats, the latter requiring only 2 per cent, while the former require about 12 per cent and also require about 10 per cent or more of butter fat to provide sufficient fat-soluble vitamin, and even then they may develop leg weakness and friability of the bones, indicating some factor necessary for chick growth and development that is not so essential in mammals.

The Washington station found that a satisfactory growth could not be maintained with rats on wheat, and there was no reproduction, but this was overcome by adding 0.29 to 0.35 per cent of soda to the ration. Growth and reproduction were normal when the wheat ration was supplemented by protein and fat-soluble A vitamin, if a proper adjustment of the inorganic elements, calcium, chlorin, and sodium was made.

Digestibility studies.

The Texas station finds considerable variation in the digestibility of pentosans from different sources. The nitrogen-free materials other than pentosans, starches, and sugars are less digestible than these. In concentrated feeding stuffs these three constituents account for nearly all of the nitrogen-free extract, but not in the coarser feeds.

Tests were made at the North Dakota station of the digestibility of prairie-grass hay. In samples cut in the spring, at the height of the growing season, and at maturity, that cut at the height of the growing period gave the highest coefficients of digestibility, was more readily eaten, and was apparently more palatable. Little difference was noted between the hay cut in the fall at maturity and that left uncut to weather over in the winter.

Acidity of rations.

At the Iowa station swine were fed a basal ration with an addition of as much as 300 cubic centimeters of normal sulphuric acid per day. There was no marked evidence of ill effect on the carcass, the fat, or the mineral content of the bones. There was a slight decrease from normal in the alkali reserve of the blood. No ill effects

were noted in the second generation. With rabbits, the progeny of acid-fed parents made normal growth. A highly acid ration was fed to rats for three generations with normal growth and reproduction.

ANIMAL HUSBANDRY.

Effect of age on gain.

In studies on the effect of age on gain of beef cattle, at the Nebraska station, the youngest cattle proved the most economical in cost of gains. At the end of a 200-day period the average daily gain was 2.21 pounds for the 2-year-olds, 2.21 pounds for the yearlings, and 2 pounds for the calves. The feed required for 100 pounds of gain was 619.46, 515.84, and 458 pounds, respectively. The calves made as much gain from 77.5 pounds of feed as did the 2-year-olds from 100 pounds or the yearlings from 86 pounds.

Silage feeding.

A summary of three feeding experiments at the Kentucky station, comparing corn and sorghum silage, shows that the corn silage steers gained an average of 0.24 pound more per day than the sorghum silage steers; the cost of producing 100 pounds of beef was $2.71 greater in the sorghum silage lot; the selling price of the corn silage steers was 12 cents per hundredweight greater; an acre of sorghum silage and supplementary feeds produced 36.4 per cent more beef than did an acre of corn silage and supplementary feeds; and the cost of producing an acre of corn silage was $42 as compared with $57 for an acre of sorghum silage. All factors considered, the sorghum silage was only 92.2 per cent as economical as is corn silage for beef production. At the Indiana station feeding trials showed no appreciable difference between silage from corn, and soy beans grown together and corn alone, either with or without cottonseed meal as a supplement.

At the Mississippi station the cheapest gains were made on corn silage and cottonseed meal. The greatest gains were made when a liberal ration of corn was fed, but this also proved the most expensive.

At the Wyoming station sunflower silage produced a little less gain than oat and pea silage. The largest and cheapest gains were made with native hay and cottonseed meal.

At the Oklahoma station sheep readily ate silage made from broom corn stalks with the heads removed. Digestion trials showed that it was equal in feeding value to silage made from other grain sorghums. The Montana station believes that failure of sunflower silage to cure satisfactorily in some localities to be due to its low sugar content, irrigated plants being exceptionally low in sugar. Mannitol is found in sunflower silage in large quantities reaching a maximum and then diminishing until it largely disappears.

White versus yellow corn.

Studies on the nutritive value of yellow corn, at the Nebraska station, indicated a deficiency of ash constituents. Supplementing with 5 per cent of a complete ash mixture improved the ration so as to enable very slow but persistent growth. It is deficient in qualit

and quantity of protein. The addition of more corn protein as corn gluten did not markedly improve the ration, but the addition of 15 per cent purified casein improved it quite decidedly. Supplementing with certain other proteins, such as egg albumin and gelatin, lowered rather than raised the efficiency of the ration, perhaps due to the sticky physical character of the supplement. The fat-soluble vitamin did not seem to be a limiting factor, for the addition of butter fat to a ration of yellow corn, casein, and ash did not improve but rather lowered the efficiency. Green feeds were found to be valuable additions to a ration for growing chicks. In comparisons of the nutritive value of white and yellow corn for growing chicks, better results were secured in all cases with yellow corn.

In feeding results at the Wisconsin station yellow corn produced decidedly larger and more economical gains than white corn when fed to pigs not on pasture, with such supplements as skim milk, whey, or linseed meal. For pigs on good pasture there was very little difference. With two lots of common feeder pigs, one fed a mixture of yellow corn and tankage and the other white corn and tankage, both in the self-feeder, the former gained 1.06 pounds per day and the latter 0.63 pound. Those on yellow corn required 447 pounds of the ration for each 100 pounds of gain, while those on the white corn required 554 pounds. Similar results were obtained when skim milk was substituted for the tankage. The results indicate that white corn should not be used for feeding pigs in winter in the dry lot but should only be used for feeding pigs on summer pasture, or for other stock. At the Kansas station also gains were made on yellow corn at a less cost than on white corn, and similar results were also obtained with sheep.

Wool.

Shearing tests at the Texas station show that shearing twice a year produced about 1 pound more wool per annum than one shearing and the sheep made 2 pounds more gain per head, but the indications are that, taking the extra cost into consideration, the advantage, if any, is small. The Montana station finds that feed has a considerable effect on the weight of fleece, length of fiber, and amount of grease, and probably on the strength and elasticity of the fiber.

Wool investigations at the Wyoming station show that exposure to the weather is destructive and is more injurious to the strength than is alkali, if the latter is dry. Open fleeces suffer most from weathering, owing to exposure. A study of the various materials that make up the impurities of unwashed wool, suint, sand, and dust, and ether soluble materials, showed that suint is more sensitive to moisture changes than the fiber itself, and a wool high in suint is more hygroscopic. The fat has about the same hygroscopic properties as the fiber, the inorganic materials having least. Studies on the change in moisture and weight when wool is brought indoors from outside, and vice versa, show this to be roughly proportional to the surface area. It is more rapid at first and diminishes until an equilibrium is reached.

Feeding trials with hogs.

The South Carolina station reports that in a study of protein supplements for hogs, fish meal proved to be slightly superior to tankage and contains more mineral matter. The Pennsylvania sta-

tion also finds fish meal to be an economical and efficient source of protein as a supplement to corn, oil meal not being so satisfactory. Semisolid buttermilk made lower gains and required a greater amount of feed to produce 100 pounds. Pigs fed in dry lot made lower gains than those on forage. At the Washington station no marked difference was found between fish meal containing 56 per cent of protein and tankage containing 60 per cent. Coconut meal was found to be bulky and somewhat unsatisfactory as a protein supplement, especially in rations for young pigs. In similar studies at the Indiana station, fish meal proved fully equal to or slightly better than tankage. Soy bean oil meal was practically equal to tankage, while ground soy beans were not as efficient and were unpalatable. Buttermilk proved the most efficient of the supplements tested, semisolid buttermilk being less so.

At the Nebraska station tankage proved to be a more economical protein supplement than shorts, increasing the rate and economy of gain. On an average, 24.56 pounds of semisolid buttermilk replaced 12.67 pounds of tankage and 33.28 pounds of corn.

In feeding tests carried on at the Missouri station, lots were fed sunflower seed alone, with different amounts of corn, and with corn alone, compared with a check lot on corn and tankage. The lot fed on corn alone proved better than the lot fed on sunflower seed alone. Equal parts of sunflower seed and corn proved to be the best combination and compared favorably with the usual Corn Belt ration of corn and tankage. While the gain from sunflower seed alone was fairly satisfactory, the pork was decidedly soft.

The Oregon station finds molasses to be a satisfactory substitute for barley, up to 40 per cent, being fed mixed with grain in the self-feeder. Coconut meal supplemented with tankage was found to replace barley, up to 25 per cent, and was a little cheaper. At the Kansas station the value of alfalfa as a supplement to corn and tankage or kafir and tankage was demonstrated, and after feeding this for three generations the lot receiving this combination was the best.

In experiments at the Vermont station, pigs carried from birth up to four or more times their original weight on normal milk, evaporated milk, powdered milk, and reconstructed milk, gave the best results with whole milk powder, this being better than normal whole milk. Reconstructed milk gave the least satisfactory results.

Tests of feeding mesquite beans to swine, at the New Mexico station, showed that 140 pounds of the beans were equivalent to 100 pounds of grain. Tornillo beans showed a good feeding value but must be ground.

Results obtained at the Alabama station show that when velvet beans are fed to brood sows they do not produce good litters, the pigs being weak; the sows had very little milk and the pigs died within a week. When fed to growing pigs these failed to grow and fatten.

Forage crops for hogs.

At the Pennsylvania station rape alone proved superior to rape and oats, or rape, oats, and peas grown together, and gave forage for a longer period. The North Dakota station finds great economic

advantage in using pasture crops for hogs in the State, and that March-farrowed pigs secure much more value from pasture during the season than May-farrowed litters.

The Oklahoma station reports very satisfactory gains of 1.55 pounds daily for 60 days with amber cane, which was only exceeded by corn and barley. Oats proved of low feeding value for hogs. Darso and kafir were found to have about 95 per cent the feeding value of corn. In all tests ground grain gave better results than whole grain.

Forage-crop tests at the Mississippi station showed the largest daily gain from a lot grazed on soy beans and corn, growing together, this being 1.56 pounds. The Virginia station reports that in a comparison of hogs on forage only with those receiving corn and tankage in the self-feeder, the former were cheaper to raise, but those receiving the supplement came on the market earlier and brought a better price. The most economical method is to supply hogs on pasture about 50 per cent of the concentrated feed which they would require if they were not on pasture.

At the Kentucky station hogging down corn alone produced 401 pounds of pork per acre, with $28.72 net profit. By supplementing this with tankage, self-fed, 535 pounds of pork were produced with a net profit of $36.05 per acre. Hogging down corn and soy beans grown together produced 347 pounds of pork, with a net profit of $19.41 per acre. By hogging down soy beans alone, supplemented with 2.5 per cent of the body weight of corn per day, 846 pounds of pork was produced per acre with a net profit of $16.72. Hogging down soy beans alone, supplemented with corn in the self-feeder, there were produced 1,114 pounds of pork per acre, but with a loss of $6.01.

At the Missouri station hogging down corn and soy beans, with and without supplements, showed that the feeding of tankage in a self-feeder to hogs on corn materially increases the rate as well as the economy of gain, and that when soy beans are planted with the corn they will not completely take the place of the tankage, an acre of corn pastured off with hogs producing more pork if tankage is fed in addition than will an acre of corn and soy beans hogged down without additional supplement.

Soft pork studies.

Extensive investigations on soft pork have been carried on by a number of the southern stations, partly in cooperation with the United States Department of Agriculture. At the Florida station tests of the fat of live hogs, before putting them on a softening ration, showed considerable individual variation in the melting point. This difference is also shown in the way in which individuals soften and harden on different feeds. Ordinarily six weeks on corn will harden up a soft hog. The rate of gain has nothing to do with the amount of softening. It is believed that internal parasites may play a part in causing the condition.

At the Kentucky station it was found that soy beans will produce a soft pork, but were not as bad in this respect as peanuts. They tend to darken the carcass as well as soften it. The Mississippi station reports that the average daily gain on peanuts alone was 1.29 pounds, and when these were grazed, with grain, 1.47 pounds.

A comparison of the effect of feeding peanut press cake containing practically no oil and whole peanuts at the North Carolina station showed that hogs receiving the whole nuts were more oily, those receiving the press cake being classed as medium.

At the Georgia station it was found that the soft and oily fat of hogs which had been fed on peanuts was not thoroughly hardened after a two months' finishing feed of corn and tankage or cottonseed meal. Classification of the firmness of the carcass by inspection in the cooling room did not consistently agree with the hardness of the fat as indicated by melting point and iodin number determinations. At the Texas station, among lots receiving varying percentages of rice bran in their ration, those receiving as much as 90 per cent were classed as slightly soft.

Poultry feeding.

Inbreeding experiments at the Wisconsin station reached a point, in mating brother and sister, where the eggs did not hatch. Selection on the basis of vigor did not give satisfactory results. At the Missouri station pullets hatched from hens laid 12.6 eggs more per bird than did those hatched from pullets. Other factors favoring high egg production are early hatching, beginning laying early in the season, and early maturity.

Starting at the North Carolina station with a common flock that averaged 89 eggs per hen per year, one lot, mated with common cocks, gave offspring averaging 91 eggs; another lot, mated with pedigreed sires, gave offspring averaging 135 eggs. Cocks from the latter, mated with common pullets, gave a progeny averaging 138 eggs, showing that the improvement came through the sires. Of two brother cocks, one is transmitting high egg production, the other low.

Egg production.

The North Carolina station has observed that hens tend to choose a more basic ration when laying, and when this period is over less mash is eaten, giving the ration a more acid character. At the Oklahoma station wet mash increased egg production in winter, but did not pay when extended beyond March. It is noted that culling by means of external characters should be done soon after the egg-laying period is concluded. After molting has been completed it is difficult to cull in this manner.

The Nebraska station finds that egg size, a character having a distinct commercial value, can be influenced by the proper selection of breeding stock.

Experiments at the Kentucky station show that laying hens whose supply of calcium is limited to that naturally occurring in the food will continue laying eggs until there is a general depletion of magnesium, phosphorus, and calcium in the bones and carcass, and as long as the economy of the hen permits the formation of an egg shell the contents of the eggs remain quite constant, but with a gradual thinning of the shell. The addition of limestone or oyster shells to the food of such depleted hens increased the egg production 69.4 per cent.

As a result of feeding experiments at the Kentucky station it is found that a low egg production by yearling hens results from a lack

of animal protein in the ration. Protein studies at the Missouri station show that cottonseed meal apparently has a retarding effect on egg production. One pen fed no protein concentrates averaged 39 eggs per hen, while one fed a slight amount of tankage laid 104 eggs. The number of eggs laid varied in proportion to the amount of animal food (tankage) in the mash.

Incubation, hatchability, and vigor.

Incubator studies at the Indiana station show that a temperature of 101 to 102° F. throughout the hatch will give the best results, 100° being too low and 103° too high, the latter being more damaging than low temperatures. The Kansas station finds that the fourteenth and nineteenth days are the critical ones as regards mortality in incubation. Hatchability is found to be affected by feed, one lot fed a standard ration, including green feed, with run of yard, had a hatchability of 62.6 per cent as compared with 8.6 per cent in a lot receiving an inadequate diet, low in water-soluble vitamin B, with no exercise. Examination of a large number of eggs that failed to hatch showed many of these to contain bacteria of the colon group, which were traced back to the hens laying the eggs, indicating the probability of ovarian contamination.

Tests made at the North Carolina station of turning incubator eggs one and five times showed 19 per cent in favor of turning five times. Spraying eggs gave a 10 per cent greater hatch. The Connecticut Storrs station found that hatchability materially increases with the size of the egg. Porous shelled eggs, allowing of more evaporation, give a low hatch.

A study of the factors affecting the vigor of the embryo has been in progress at the West Virginia station. In a comparison of a corn and wheat ration the latter gave a larger egg, and a positive correlation was found between the size of egg and vigor of the embryo. In tests of the effect of confinement, it was found that 2,268 eggs laid by confined hens averaged 66.63 grams in weight and 3,873 eggs from hens on the range averaged 57.94 grams. Twenty-three per cent of the eggs from the confined hens and only 13 per cent from the range hens were infertile. Sprouted oats had no effect on the number, but did have a marked effect on the fertility and hatchability. Green feeds seemed to diminish the weight of the egg about half a gram. In the green-fed lot 18 per cent of the eggs were infertile as compared with 24 per cent of those from hens not receiving green feed.

Feeding chicks.

At the Wisconsin station sweet skim milk proved to be better than sour skim milk or buttermilk. Chicks receiving a basal ration containing skim milk were twice as heavy at the end of three weeks as those on a ration not containing it. Chicks on milk albumin did not do as well as those on meat scrap, and dried buttermilk was not as good as skim milk. Skim milk gave better results than any other animal feed except whole milk. Fish scrap gave gains inferior to beef scrap.

At the Wisconsin station chicks receiving single-grain rations of barley, white corn, or wheat made good growth on all three feeds when 10 per cent of butter fat was added, but below 10 per cent the chicks either died or did not gain. Three lots of laying hens were

fed white corn, one lot receiving in addition skim-milk powder, another lot dried hog liver, and a third lot 1 per cent of cod-liver oil. Health was not maintained on the skim-milk powder, but the other lots did well. The hog liver imparted no color to the eggs.

In investigations at the West Virginia station on the after effect of chick feed, small chicks were fed a low- and a high-protein ration. The low-protein lot laid eggs that were 10 per cent lower in weight, and they were 20 days later in laying the first egg than those receiving the high-protein ration. The first year there was an average of 123 eggs from the high-protein lot and 96 from the low-protein lot. An average of the weights of 7,000 eggs showed a difference of 0.66 per cent in favor of the high-protein lot.

It was found at the Kentucky station that chicks that have once received grit will always retain sufficient in the gizzard, even if they never receive any more, and if hens receive a ration that contains sufficient lime it is not necessary to feed grits.

DAIRYING AND DAIRY FARMING.

Raising dairy calves.

A comparison has been made at the Mississippi station of early and late fall calving, the results now including three years' observations. The early fall calving included dates from August 1 to October 1 and the late fall calving from October 1 to December 30. There was an average difference per year per cow of 683 pounds of milk and 27.5 pounds of butter fat in favor of late fall calving. A comparison of spring and fall calving showed a difference in favor of fall calving. Observations on the cost of raising calves showed that the least expensive gains were made by Ayrshires, next by Holsteins, and next by Jerseys.

At the Iowa station it was found that $109.89 was the cost of feed to raise a calf dropped in winter from birth to first freshening, at which time the weight was 1,010 pounds. Summer calves cost $102.43 and weighed at freshening 941 pounds. Heifers dropped in the winter increased 1,385 per cent in live weight from the date of birth to date of first freshening. There was an increase of 72 per cent in height at the withers, 128 per cent in depth of body at heart girth, and 183 per cent in width at hip bones. Those dropped in summer increased 1,370 per cent in weight, 71 per cent in height, 129 per cent in depth, and 200 per cent in width.

Growth-curve studies at the Missouri station show that the dairy calf passes through two cycles during the extra-uterine period of growth, with maximums at about 5 and 20 months of age. Data obtained indicate also that the calf passes through a cycle in utero, with the maximum at about two months before birth. Growth at a rate approximating normal can be secured by weaning thrifty dairy calves at about 60 days of age.

At the Minnesota station the total feed requirements to raise a dairy calf to 6 months of age, when fed with a minimum amount of milk, is found to be approximately 500 pounds of milk, 450 pounds of grain, and 275 pounds of hay. Animals under 10 months or a year of age require the full amount of nutrients specified by Armsby's standard. Less nutrients are required as the age of the animal advances, until at 18 months apparently about 80 per cent of the

Armsby standard is sufficient. Data secured at the Indiana station indicate that the feed used for calves up to 6 months old has no effect on the vigor of their offspring later.

At the Missouri station Holstein heifers showed a slightly better development than Jerseys on the same protein plane. Very little relation was found to exist between the protein plane and the skeletal growth as indicated by height at withers, but there was a rather definite relation between the protein plane and increase in weight. From the data available it would appear that a 20 per cent plane (20 per cent of total energy from starch) is approximately correct for growing dairy animals, both Holsteins and Jerseys.

At the Arizona station it has been shown that by feeding calves a quart of milk daily after they are 1 month old, and supplementing this with either commercial or homemade calf meal, well-developed calves can be raised. A mixture of three parts corn meal, two parts wheat bran, one part linseed-oil meal, one-half part blood meal, two parts ground bone meal, and three parts of wheat middlings made a very satisfactory ration for young calves as a substitute for milk. At the Washington station dairy calves were successfully raised from the age of 3 weeks up to 4 to 6 months on condensed buttermilk instead of whole milk.

Attempts to raise young dairy calves at the Oregon station wholly on homemade calf meals, consisting of various combinations of mill-run, ground barley, ground red-clover hay, ground oat and vetch hay, oil meal, and soy-bean meal were not successful, and it was necessary to supplement this with milk.

The Montana station reports a comparison of feeding dairy calves a whole-grain mixture of oats, barley, and a little oil meal in a self-feeder with the amount they would eat in 15 minutes hand fed three times a day. The self-fed lot ate more grain, but did not make as good gains as the hand-fed lot, as they evidently ate too much and went off feed for a time.

At the Missouri station the best results were obtained when calves were put on a grain and hay ration at about 60 days of age.

Milk production.

In studies at the Iowa station on individual variation data were obtained on two half-blood full sisters, having a full blood sire, out of a scrub cow, whose average record was 5,258.9 pounds of milk and 233.69 pounds of fat. One of the daughters averaged during her lactations 3,639 pounds of milk and 180.5 pounds of fat, a decrease from her dam's record of 31 per cent in milk and 23 per cent in fat. The other daughter averaged 6,128.4 pounds of milk and 298.33 pounds of fat, an increase over her dam of 17 per cent in milk and 28 per cent in fat. They were under the same conditions of feeding and management.

Studies on the relation of age to milk yield at the Maine station show that this increases up to about 8 years and 3 months and then declines slowly. Butter fat percentage declines slightly from an age of about 2 years to 14 years.

Data secured at the Washington station show that an average cost of producing 100 pounds of milk, delivered at the local plant or shipping point, was $2.88, the cost on different farms ranging from $1.94 to $4.39. Feed constituted 48.31 per cent and man labor 24.2

per cent of the total cost. One hundred pounds of milk was found to require 18.78 pounds of grain, 42.13 pounds of hay, 49.5 pounds of silage, 5.6 pounds of roots or kale, 0.093 month of pasture, and 2.19 hours of man labor.

Comparison of grain feeds.

In a comparison of home-mixed and ready-mixed commercial feeds, at the North Carolina station, the home-mixed feeds proved to be more palatable, cost $22 per ton less, and produced more milk.

In experiments at the Wisconsin station to determine whether dairymen can supply their herds with satisfactory home-grown rations, avoiding the necessity of buying expensive concentrates, it was demonstrated that cows would keep up quite a large flow of milk without losing nitrogen from their bodies if fed an abundance of alfalfa hay, corn silage, and corn. It was found that if barley or oats are fed as the grain, in amounts supplying the same amount of protein, starch must be added to compensate for the lower net energy of these grains. Dairy cattle fed a well-balanced ration of alfalfa hay, corn silage, corn, and oats maintained as good production as on a higher nitrogen ration containing cottonseed and linseed meals.

The North Carolina station has conducted experiments on the effect of cottonseed meal on growth and reproduction. Young animals receiving a ration of half cottonseed meal and half corn silage all became sick, and one died. Another lot receiving somewhat less cottonseed meal and hulls, with cracked oats, became sick, weak, and off feed. Four mature cows receiving over 14 pounds of cottonseed meal daily calved normally, and the calves were at first normal, but after four weeks one became blind and another nearly so.

Feeding experiments at the Iowa station showed that 100 pounds of corn meal was equivalent, for butter-fat production, to 125 pounds of corn-and-cob meal or 140 pounds of ear corn. Very little difference was noted in the value of shelled corn, cracked corn, and corn meal. Ear corn was about 12 per cent less valuable than corn-and-cob meal. Cracked soy beans proved to be worth about 30 per cent more than old-process oil meal for feeding milk cows in connection with corn silage, alfalfa hay, cracked corn, and ground oats.

Experiments at the West Virginia station indicate that soy beans are equal or slightly superior to alfalfa for milk production; and the Missouri station reports that soy beans appear to be better than alfalfa hay as a supplement to a grain mixture of corn chops, 4 parts, with wheat bran and oil meal 1 part each, on account of their apparently greater palatability.

A comparison of velvet bean meal with cottonseed meal, at the North Carolina station, showed that the former is unpalatable, lacks bulk, and produces less milk.

At the Georgia station peanut meal, up to 6 pounds, and whole nuts, up to 4 pounds, were fed with corn silage. The whole nuts appeared to give a harder butter than the meal. No flavor was imparted to the butter.

Tests at the Wisconsin station indicate that hydrolyzed sawdust prepared by treating with weak sulphuric acid under pressure, neutralizing with lime, and centrifuging to remove the calcium sulphate,

may be substituted for corn or barley in the concentrate mixture for high producing dairy cows without affecting the normal milk flow, to the extent of one-fourth to one-third of the concentrate mixture. It is found to be worth about one-half as much as barley in feed for dairy cattle.

Roughage for dairy cows.

At the Virginia station corn silage proved to be the most desirable roughage if supplemented with a good protein-rich concentrate, such as cottonseed meal, soy-bean meal, or linseed meal. At the West Virginia station a comparison of sunflower and corn silage showed that the former did not keep up the milk supply as well as the latter. The Wyoming station reports no significant difference in sunflower silage and oat and pea silage for dairy cows, both being of about equal value in increasing body weight and in the feed cost for producing 100 pounds of milk and 1 pound of butter fat.

The Oregon station reports that sunflower silage produced 100 pounds of fresh milk on less feed than corn or oats and vetch silage, but the amounts consumed did not maintain the body weights, and it was not as palatable as the other silages. It imparted no flavor to the butter. Reports from the Pennsylvania station indicate that sunflower silage is not as palatable as a mixture of sunflower and corn silage and is inferior to a good grade of corn silage for milk and butter fat production.

Results obtained at the North Dakota station indicate that sunflower silage is almost as good as corn silage, although it ranks low in palatability, and that good sweet clover silage is equal to corn silage for milk production.

Red clover was ensiled successfully at the Pennsylvania station and proved to be superior for milk production to a ration in which dry hay alone formed the roughage.

Tests at the Connecticut Storrs station indicate that silage corn varieties which mature there have a higher feeding value pound for pound, than varieties which do not mature, and effect a saving of about 5 pounds of grain for each 100 pounds of milk.

The Minnesota station reports no ill effects from feeding moldy silage to dairy cows. The cows ate the silage freely after becoming accustomed to it.

In a comparison of alfalfa and Sudan hay for dairy cows, at the Arizona station, the cost of milk produced on the alfalfa ration was 14.7 cents per gallon and on the Sudan grass 15.8 cents. The alfalfa lot produced 500 pounds more milk and 20 pounds more butter fat in the four-months' feeding period.

Qualities of milk.

Studies at the Minnesota station lead to the conclusion that milk may be regarded as an emulsion of the oil-in-water type and butter an emulsion of the water-in-oil type. The Wisconsin station finds that some lots of milk at condenseries coagulate to a solid mass, which was formerly thought to be due to acidity, but is found to be apparently due to a disturbance of the balance of calcium salts and the citrates and phosphates. It can often be prevented by the addition of small amounts of sodium citrate or bicarbonate, although

in some cases the latter may be harmful and hasten the coagulation. An excess of any of the normal milk salts, sodium citrate, sodium or potassium phosphate, or calcium chlorid, hastens coagulation. The balance is delicate, but the remedy is simple.

Results obtained at the Minnesota station indicate that what is usually regarded as a change of soluble into insoluble calcium phosphate when milk is pasteurized or boiled is really the coagulation of the colloidal calcium phosphate of the milk. The lower the calcium-ion content of the milk the higher the hydrogen-ion concentration, within a certain range, which is required to produce a normal clot. The colloidal dicalcium phosphate probably does not play a part in rennet coagulation. It is found that abnormal fermentation, occurring occasionally in advanced lactation in individual cows, referred to as "bitter," "rancid," "strong," etc., is the result of lipase action.

The Iowa station finds that the cause of a burnt or caramel flavor in dairy products, thought to be due to overpasteurization, is really due to an organism.

The Connecticut Storrs station reports that in the cleaning of milking machines, immersion of the parts in hot water (180° F.) is the most reliable procedure for all seasons. A continuous stream of water under 55° F., was also effective. Steam proved ineffective and destructive to rubber parts.

In a study of the onion flavor in milk, at the North Carolina station, it was found that by blowing air through such milk for 25 minutes, at a temperature of 140 to 160° F., the flavor could be eliminated, but there is a loss of 15 per cent by evaporation. The flavor is due to the presence of allyl sulphid from wild onions consumed in the pasture and hay. As the wild onion matures the flavor grows less.

Factors influencing fat in milk.

Studies at the Missouri station on factors influencing fat in milk, show a casual relation between temperature and the percentage of fat, there being roughly an increase of about 0.15 per cent of fat for each 10° F. decrease in temperature. This is evidently due to an increased lipoid metabolism in the blood, accompanying the lowering of the temperature with the transformation of blood lipoid into milk fat. When the feed was cut there was a gradual increase in the percentage of fat, reaching a peak on the third day, followed by a drop below average for a few days. Advance of lactation exerts an influence, there being a general decline the second month, followed by a gradual increase during the remainder of the lactation period. During the summer months the fat runs low, but starting with October there is a gradual rise, reaching a peak during December, January, and February. If the cow stands quietly for two hours before milking the successive 100 cubic centimeters are very much like the successive portions drawn from a 1,000 cubic centimeter cylinder after standing two hours, but if the udder is shaken the successive portions are nearly uniform.

Similar results were obtained at the Missouri station, where a study of the milk records of 3,000 Guernsey cows showed a falling off of fat content of the milk during summer and a rise in winter, which was also found to be true of Jerseys and Holsteins. There is also

noted a decline in milk fat during the second month of lactation, followed by a gradual increase during the rest of the period. At the Maine station it was found that the butter fat-percentage secured in the advanced registry tests, as well as the milk yield thus secured, measure quite accurately what the probable yields will be in subsequent lactations.

Bacteria in milk.

The South Carolina station has made a study of the bacterial content of milk. If milk is drawn aseptically there is a retardation of the growth of the bacterial flora for the first 4 hours, but under ordinary conditions there is an increase in 2 hours, which, however, is slower if the milk is kept cool. If aseptically drawn it is sometimes 70 hours before acidity develops. The flora is found to vary somewhat with different animals and includes a number of species.

The Wisconsin station has perfected a simple and rapid method for determining the bacterial content of milk by means of methylene blue reduction.

The New York State station finds that the sanitary condition of the milk-producing farm and the methods of handling are measured by the quality of the milk produced. The quick microscopical test which has been worked out by the station has proved of great value in showing this, and is being put into practical use with satisfactory results.

Butter.

At the Iowa station, in a comparison of butter made by churning sweet and ripened cream, when scored immediately after it had reached the market, the ripened cream butter scored higher in 31 samples out of 40, in 4 samples the sweet cream butter scored higher and in 5 samples it scored the same. After two months in cold storage the ripened cream butter scored highest in 19 out of 42 samples, the sweet cream butter in 17 samples, and the score was the same in 6 samples. After nine months in cold storage the sweet cream butter scored highest in 15 out of 26 samples, the ripened butter in 7, and 4 samples scored the same. The average score in flavor was 35 for the sweet cream butter and 32 for the ripened cream butter. Tests showed that butter made from cream pasteurized at a high temperature does not keep as well over a long period of time as that from a lower temperature. At the Minnesota station, however, it was found that higher pasteurization temperatures, if the cream has a low acidity, results in a better keeping quality of the butter.

At the Connecticut Storrs station a study of the flavor and keeping quality of butter made from sweet cream, from cream with lactic starter, and from cream ripened with *Bacillus acidophilus* and stored for 8 months, showed that the last named had a superior flavor in almost every case.

Experiments at the Wisconsin station showed that when made under the same conditions, whey butter scores as high as and keeps even better than whole milk butter, and the conclusion is reached that nothing in the normal process of making whey butter makes it inferior to whole milk butter. After aging three months, whey butter, scored by 13 judges, averaged a slightly higher score

than creamery butter. Milk butter deteriorated considerably more than whey butter.

Studies at the Massachusetts station on the effect of feed in modifying the chemical and physical characters of butter show that in feeding peanuts, corn, or soy bean oil, there is a marked increase in the formation of oleic acid, linoleic and linolenic acid being transformed into oleic acid. Arachidic acid in peanut oil is apparently transformed into stearic acid.

Experiments in sterilizing butter, at the West Virginia station, show that in order to accomplish this it is necessary to heat the butter high enough to destroy enzyms, but this also destroys the texture of the butter. It can be heated under pressure, however, without producing any objectionable change.

The Michigan station finds the metallic flavor of butter to be caused by certain members of the subtilis group.

Ice-cream making.

Ice cream studies at the Missouri station show that viscosity varies directly with the fat content. The time required to begin freezing increases as the fat content increases. A 14 per cent cream is found to be a little too rich to be entirely satisfactory for the average market, from 8 to 10 or 12 giving by far the best and most easily marketed creams. An increase of overrun results from the use of sugar up to 8 to 12 per cent; beyond this amount there is a decrease. The maximum total solids for a large overrun is found to be 32 per cent. The hardness of the cream begins to decrease when the sugar content falls to about 8 per cent. In general, 12 per cent of sugar is found to be the best quantity for commercial use. In similar studies at the Oklahoma station it was found that 10 per cent of butter fat and 20 per cent of milk solids give an ice cream of satisfactory quality. It was also shown that milk powder or condensed milk gives a firmer and better keeping product, and that milk powder can be used to replace most of the cane sugar and part of the butter fat content.

VETERINARY MEDICINE.

Contagious abortion.

Studies on contagious abortion at the Kentucky station show tha the causal organism of this disease is not the same in horses as i cattle. The organism in mares is of the colon-typhoid group, tha of cattle belongs to a different group. Jennets were found to absor the germ or its products from the intestinal tract into the bloo stream if the live organism is fed to them, indicating that mares ma be infected through ingestion. It is believed that infection come mainly through the feed. A bacterial vaccine has been prepare for the disease in mares that acts successfully as a preventive fo about a year, but is not curative. For cattle, a bacterin is used, fo lowed by a live-germ vaccine, with good success. The same orga ism that causes the trouble in cattle was found in aborting sows, bu after passing through the sow it will not cause abortion in cattle.

At the Connecticut Storrs station cows, heifers, and calves we not infected by virulent cultures of the bacillus given orally in ca sules or in milk, but were infected when the cultures were give subcutaneously, interurethrally, or by applications on the surfa

of the scarified vulva. Deep vaginal applications only occasionally produced infection. Isolation and disinfection of the cow at the time of abortion, and disinfection of the bull, are effective means of control, although the latter alone is not adequate. The most susceptible time for infection is found to be at sexual maturity.

Tests at the Wisconsin station show that the abortion organisms of bovine origin will not cause pregnant sows to abort, but the organisms of bovine and porcine origin are morphologically and culturally identical, and the blood of infected sows will agglutinate antigens of both bovine and porcine origin. Among a large number of animals vaccinated for this disease, 85.9 per cent had normal calves, while only 68.8 per cent of the calves of unvaccinated animals were normal. None of a number of sows given the bovine strain of the bacillus aborted, while all but one of a number given the swine organism did do so.

Experimental trials, at the Illinois station, to produce abortion in cattle by contact with aborting sows proved negative.

In abortion studies at the Minnesota station the agglutination test was found to be superior to the complement-fixation method for diagnosis. Studies on the cause of sterility show this to be commonly due to certain streptococci combined with *Bacillus pyogenes*, and occasionally colon bacilli and staphylococci are involved. *B. abortus* is probably not only a direct etiological agent, but in many instances may prepare the way for other organisms. Treatment with lysol was of little value. In every case of abortion in mares and of joint-ill in foals, besides the *B. abortus*, a streptococcus was isolated, and cases of joint-ill were cured by injecting antistreptococcus serum.

A study of the after effects of abortion, at the Louisiana station, shows that it may produce orchitis in males and sterility in females, with fat deposits and ossification of the joints. Proper sanitation and isolation of cases are effective means of reducing the trouble.

Investigations at the Missouri station show that as a rule reacting calves apparently have the power to destroy the infection completely before reaching sexual maturity. Unbred heifers do not become reinfected by continuous exposure to nonpregnant reacting cows. The mature female host does not seem to have the power to readily destroy and effectually eliminate the *B. abortus*, but may remain a permanent carrier.

At the Oregon station, in no case has the feeding of infected milk to heifer calves resulted in infection. Breeding negative cows and heifers to negative bulls which had served positive cows did not result in infection. Twenty calves exposed to infected cows in pasture developed two cases. Exposure of pregnant heifers in pens or pasture with cows that have aborted was found to be the chief method of infection, and it may be transmitted in the barn if this is not properly cleaned. The pregnant cow is susceptible, and when fed cultures of the *B. abortus* will become positive and often abort. A milking unbred negative cow placed in a stall where cows had aborted became positive. Animals are most apt to abort during the pregnancy in which the initial infection is obtained. The organism is most readily introduced through the digestive tract, and lives indefinitely in the lactating udder.

At the Arkansas station a number of sows were fed milk heavily infected with the abortion organism from cows through three gesta-

tion periods. Abortion occurred in one case only, and from this case it was impossible to reisolate the organism. Agglutination tests with several of the sows were positive.

Physiological studies, at the California station, show little difference in the organisms isolated from aborting swine and cattle, those from swine, however, being a little more virulent toward guinea pigs. At the Michigan station about 30 strains of the abortion organism have been isolated which do not vary in morphological characters but do in virulence.

At the Kentucky station an examination of the organisms from the reproductive organs of sterile mares show that barrenness is not as common a sequel of contagious abortion in the mare as in cattle. A number of organisms were found, including streptococci in a few cases.

Hog cholera.

Hog cholera exposure experiments have been conducted at the Indiana station to study means of transmission. Healthy pigs in a pen adjacent to one containing cholera-infected pigs, when separated by an incomplete cheesecloth partition, contracted the disease, while with a tight cheesecloth partition they remained well. Healthy hogs in an outdoor pen 4 feet from a pen of infected hogs contracted the disease. After these pens had been vacant four days, susceptible hogs placed in them did not contract the disease.

At the North Dakota station it was demonstrated with two different viruses that hog cholera can be produced by the use of 1/50,000 cubic centimeters, but even this did not establish the minimal dose necessary to produce the disease, but showed that the causative agent propagates within the animal body. Membranes are impervious to the virus, which is thought to indicate its colloidal character and that it has not the property of toxin in solution. It appears to penetrate parchment, such as goldbeaters' skin, but it apparently does this by a process of growth. While it will not dialyze through parchment, goldbeaters' skin, or collodion capsules in artificial media, it will do so when normal hog or horse serum is used as the dialyzing fluid. Neither oxygen gas, distilled water, or acetic acid show any appreciable attenuating influence upon the virus. Precipitation of the globulins of blood serum hog-cholera virus by means of carbon dioxid gas, and of the globulins and albumins by half and complete saturation with ammonium sulphate, failed to remove the causative agent.

The Kentucky station confirms previous reports that the virulence of hog-cholera virus is increased by shaking with glass beads. Organisms from cases of cholera have been successfully grown in a specially prepared medium, which when stained shows chains of cocci-like bacteria.

Studies on the possibility of the transmission of tuberculosis through the injection of hog-cholera serum at the Missouri station show that while tubercle bacilli actually circulate in the blood of tuberculous swine and the disease can be transmitted by inoculation into others, the methods followed in the careful preparation of anti-hog-cholera serum eliminate practically all possibility of such transmission. In regard to secondary infections it is shown that the

organisms of hemorrhagic septicemia, infectious pneumonia, and mixed infections are not primary causes of infectious diseases, but are commonly inhabitants of the alimentary tract and larger air passages, and are not harmful to healthy swine until their resistance is lowered. The proper use of anticholera serum and proper sanitation to prevent worm infection will also prevent complications from secondary infections, and vaccination against the latter is of doubtful value.

Hemorrhagic septicemia.

Investigations at the Kentucky station show that hemorrhagic septicemia occurs only rarely as a primary infection, and rather definite predisposing factors are essential, especially with swine. Pure cultures of the microorganism, when injected into swine, seldom produce the disease, except when a considerable quantity of a highly virulent culture is given intravenously. Subcutaneous, intramuscular, and intratracheal injections and feeding did not produce the disease except in cases where the animal was suffering from some other ailment at the time of the injection, and if the predisposing causes can be controlled, losses from this disease may be materially reduced.

Studies on the pathogenicity of *Bacillus bipolaris* (bovine) at the Nebraska station show that the injection of virulent cultures in normal calves produces only transitory illness, with quick recovery, the illness being mainly characterized by articular disturbances. When the injection is made, however, in connection with a nonfatal anaphylactic reaction, more severe illness and death may result, in which *B. bipolaris* is a determining factor, and repeated injections with autogenous bacterins afford no protection. The apparent proclivity of the organism to localize and cause lesions in bones and joints is a prominent difference between induced and natural infection. Immune serum against *B. bipolaris* can be prepared in the usual manner, and this protects animals against otherwise virulent injections, but the protection is of short duration only. Studies at the Colorado station indicate that a live organism vaccine for this disease is more valuable than one killed by heat or antiseptics.

Tuberculosis.

A case of equine tuberculosis is reported by the Wisconsin station. The disease being rather rare in this animal, it was investigated and proved to be of the bovine type rather than the human or avian. Guinea pigs and rabbits inoculated with bacilli from a pony having the disease contracted it but cockerels did not. The station has perfected a method of preparing a vaccine by killing the organisms with ultra-violet light, which has proved quite successful.

At the California station it was found that about 50 per cent of reacting animals showed no tubercle bacilli in histological studies, but many showed enlarged lymph glands, although cultures from these failed to produce the disease in experimental animals.

At the Illinois station calves inoculated with the avian type of tuberculosis in some cases developed lesions, but no evidence was obtained to show that tuberculosis of poultry is communicable under natural conditions to cattle.

Botulinus.

It has been shown at the Kentucky station that there are two types of *Bacillus botulinus*, A and B. Antitoxin produced for type A will not protect against the toxin of type B, and vice versa; and since it is not known which type is responsible for botulism in any given case it is necessary to use antitoxins protecting against both strains.

The Illinois station reports the practicability of employing chickens for the purpose of differentiating A and B botulinus in food, the positive value being limited to the type A toxin, which, if present, is manifest in a general paresis and coma a few hours after the ingestion of contaminated food. *B. botulinus* has been isolated from several samples of soil, from water of a pond in which fish were dying, from dead fish from an infected pond, from many animal foods and animal secretions, including the milk from an artificially infected cow; also from human foods, including canned string beans and spinach, pimentos, olives, flour, graham and rye breads, and stale ice cream cones, doughnuts, and cakes of various kinds. The spores of some strains appear to be sufficiently resistant to survive the temperature of cooking doughnuts. In some instances proprietary mineral mixtures sold as " tonics " for animals have been found to be contaminated with *B. botulinus*, type A or B.

A sample of corn silage which was causing illness and death of cattle was found to contain the botulinus organism. Animals treated with antitoxin were fed the same silage without ill results. It is thought that a protective toxin for the treatment of botulism can be prepared by injecting increasing doses of the toxin into horses. When A and B toxins are thus used to produce the antitoxin, the reaction is sometimes severe. More consistent results have been obtained by hyperimmunizing horses with only one of the toxins. Botulism in horses, cattle, and swine was traced to feeding flour or stale bakery goods. Viable spores were found in 58 per cent of the flour from local kitchens. The spores develop better at a low than at body temperature.

Anthrax.

The Louisiana station has made extensive studies on anthrax. Investigations on the diagnosis between the true and pseudo-anthrax bacilli show the former are capsuled while the latter are not, and it is fairly safe to diagnose anthrax on this characteristic, but if the capsuled forms are not found it is not safe to conclude that it is not present. Cultural methods do not serve to distinguish them. Nonanthrax forms are motile, but both may grow in chains. The only positive and sure means of diagnosis is by animal inoculation, which takes from 3 to 4 days. Early treatment with antianthrax serum will save 75 per cent of a herd, but the temperatures must be closely watched and the treatment repeated. The infection may be present in the soil, and rainy periods are supposed to cause outbreaks. Soils moistened with water containing the spores and then dried out showed the spores still virulent for guinea pigs. It is also found that the Argentine ant may act as a carrier, and all blood-sucking insects, as flies and mosquitoes, may carry it mechanically, but it does not undergo any phase of its life cycle in them and does not appear to pass through them, except as spores, although the regurgitations are full of bacteria. The bacilli remained virulent for guinea pigs for a

period of 12 years while suspended in lake water. They have remained virulent in milk for a period of 10 years, and for a period of 9 years in dog feces. Negative results from cultures from decomposed blood or flesh are not conclusive evidence for a negative diagnosis.

Necrobacillosis.

The Wyoming station reports that treatment of necrobacillosis by washing the parts with Dakin's solution, containing 10 per cent of potassium permanganate, has been successful if the lesion can be reached. It is thought that the organism lives over in the soil and is transmitted by feed or water. The immunization of rabbits has been successful. Death is found to be due to toxemia. By using a medium of alkaline pyrogallate, which gives anaerobic conditions, the organism can be grown for a few days.

The Montana station reports that necrobacillosis in sheep is apparently associated mainly with management and the weather. It occurs mostly in large bands of sheep, subjected to rough, cold weather and filth.

Swamp fever.

Attempts to pass the virus of swamp fever through hogs have been unsuccessful at the Texas station. Pigs inoculated with the active virus remained healthy, and 21 days after the inoculation blood from these pigs injected subcutaneously into a horse produced no results.

Careful search of the blood of horses which died of the disease failed to demonstrate the spirochaetes claimed by Japanese investigators to be the cause of the disease. Experiments as to its transmission by stable flies have thus far been negative. Inoculations made with serum received from the North Dakota and Wyoming stations were negative, which may indicate that there are biologic strains of the disease.

At the North Dakota station it was found that the virus will dialyze through animal membranes, as parchment and gold beaters' skin, indicating a crystalloidal nature. In artificial media the average incubation period, as noted in 13 years' observation, is from 11 to 13 days, with a minimum of 9 days, excluding one very virulent strain, recently found, which had an incubation period of only 72 to 96 hours. All attempts to inoculate swine with the disease have been unsuccessful.

At the Wyoming station horses were inoculated with filtered and unfiltered nasal secretions from an infected animal. The unfiltered material gave a fever reaction in a few days, which was shown to be swamp fever. The results with the filtered material were not definite. No positive results were obtained by transferring eye secretion of an infected horse to an uninfected one.

Poultry diseases.

The Nebraska station finds that none of the fowl cholera vaccines on the market is of any value. The disease is caused by *B. bipolaris*, the same organism causing hemorrhagic septicemia in cattle and pigs. It is not very easy to produce the disease by inoculation of the organism into cattle, and when successful there is an apparent proclivity of the organism to localize and cause joint trouble. A preventive

serum has been made that is effective against artificial infection, but the protection is of short duration only.

The Rhode Island station finds that in the agglutination test for the diagnosis of white diarrhea the reaction varies with the strain of *Bacterium pullorum* present, and may therefore be unreliable in some cases. *Heterakis papillosa* has been found to aid in producing blackhead. Infection was found to be direct, with no passage through the tissues after the larvæ reach the intestines.

At the Illinois station the examination of a number of cases of limber-neck in poultry showed that there are apparently some types of this trouble which are not related to *Bacillus botulinus*, type A or B. Symptoms of botulism have been produced by feeding certain unidentified, heat resistant, rod-shaped organisms to guinea pigs, and botulinus antitoxin of either type failed to protect against this anaerobe. The Indiana station also reports that in some cases the antitoxin gives no protection. Infection seems to come from eating maggots from decayed flesh. Some cases recover.

The Kansas station reports that satisfactory results have been obtained by the use of chicken roup vaccine in more than 10,000 birds.

Miscellaneous diseases.

The Nevada station has made an exhaustive study of a hemorrhagic disease occurring in cattle. Three anaerobic organisms were isolated from the livers of diseased cattle, viz, *Bacillus welchii*, *B. edematiens*, and *B. botulinus*. The first two are believed to be directly connected with the disease. Cultures of *B. edematiens* reproduced the disease in a much more rapidly developing form than under normal conditions. *B. botulinus* is believed to be a secondary parasite in the disease, there being in typical hemorrhagic disease no paralysis, which is a common symptom of botulinus infections. Emulsions of the organs from autopsied animals failed to produce the disease. It is seasonal in the State, appearing in May or June, increasing to a maximum in late summer, and disappearing in November or December. There appears to be also a dietetic factor in the causation of the disease.

The Louisiana station investigated an outbreak of infectious diarrhea in cattle that occured in the northern part of the State. An organism was isolated and identified as a Prowazekia, which has also been isolated from the soil, human beings, and reptiles. It appears in the winter when the cattle are in poor condition. The life cycle of the organism appears to be completed in about 10 days.

Lymphangitis in cattle is found by the California station to be caused by an acid-alcohol-fast organism. The lesions resemble those of tuberculosis, and a large percentage of cases give a positive reaction to the intradermal tuberculin test. The disease is not mammalian tuberculosis, as it failed to produce a single case of tuberculosis in a large number of inoculations in guinea pigs. A number of cattle reacting to the intradermal tuberculin test showed only enlarged lymphatic skin glands.

The Wisconsin station has successfully used johnin as a diagnostic agent for Johne's disease for the first time in this country. This is difficult to prepare on account of the very slow and uncertain growth of the organism on artificial media.

A study of temperature variations in normal cattle, at the Montana station, showed these to be wider than is ordinarily assumed. Variations of 4 or 5° F. were found in apparently healthy cows.

At the Washington station the hitherto unexplained disease known as "orchard horse disease" is believed to be due to lead arsenate on orchard grass, evidently from spraying, and when feeding of this material was discontinued there was a material lessening in the number of cases. However, horses fed artificially sprayed hay, while they showed typical arsenical poisoning, the symptoms did not fully correspond with those of typical orchard disease. Feeding hay from sprayed orchards gave a typical case and death in one instance. Inoculation from a horse suffering with the disease did not give positive results.

In investigations of swell head of sheep and goats, at the Texas station, no successful remedy has been found, and negative results were secured in all attempts to transmit the disease to healthy animals by the injection of serum, blood, or organ extracts from sick goats. Negative results were also obtained in feeding goats with Saccahuista (*Nolina* sp.), a poisonous plant which has been suspected to be a possible cause of the trouble.

Studies of a bacterial disease of goats, at the Texas station, showed this to be a new disease, infection being largely confined to the gall bladder. Two bacilli were isolated, *B. pyocyaneus* and an organism resembling *B. coli.* Ear mange of goats was found to yield well to a wash composed of sulphur and potassium carbonate.

Parasites.

The Michigan station reports that the period when ox warble flies are on the wing is very short, and if animals are kept in the barn during this period it may offer a means of control.

The Texas station reports that the use of fly traps for the control of the screw-worm fly has been quite efficient and is being widely adopted.

At the Kansas station examination of the stomachs of calves which had died from an unknown cause revealed enormous numbers of minute hair-like parasitic worms, *Ostertagia ostertagi*, sufficient to cause death. This is the second time this parasite has been reported in this country. The Louisiana station also reports a stomach worm in calves, previously reported from South America and Europe, but heretofore not found in the United States.

Studies by the Oklahoma station on the stomach worms of sheep show that the larval worms live longer than is generally claimed, in some cases as much as 16 months. Most of the infection comes from sheep drinking from cattle tracks at the edge of pools, these tracks being found full of worms. A 1 per cent solution of copper sulphate is recommended for treatment, which will remove from 75 to 90 per cent of the worms, and if tobacco dust is added the efficiency is much increased. The treatment is not of much value, however, when the worms have left the stomach and gone to the intestines, where as a rule, however, they are never found in abundance. The Texas station also reports the successful use of copper sulphate as a remedy for stomach worms when the animals have been deprived of food and water for 24 hours before and after administering it. The best

results were obtained with 3 grams of copper sulphate in 100 cubic centimeters of water, but it is believed that this can be reduced to 1 gram with more safety. The dose for sheep should be less than for goats. The Connecticut Storrs station likewise reports tobacco or tobacco extract with copper sulphate as a promising means of control of stomach worms.

Investigations on the lungworms of sheep, at the Oklahoma station, show that the larvae penetrate the intestinal mucosa, enter the lymph or blood streams, and are thus carried through the various organs, finally reaching the lungs. This was confirmed by feeding larvae to a lamb, after which larval worms were found in the blood, lymph glands, and abdominal cavity, but not in the liver or mesentery, indicating its transference by the blood or lymph. The Wyoming station reports that the muscle worm of sheep (*Sarcocystis tenella*) requires no intermediate host, infection taking place directly from sheep to sheep.

The Kentucky station reports that several organisms have been found in the intestinal tract of shoats suffering from infectious necrotic enteritis, many of which are also found in healthy shoats. The constant occurrence of *Trichomonas suis* suggests that this and possibly other protozoan forms are the cause of an acute diarrhea in shoats.

The Michigan station reports that a study of the intestinal protozoa of pigs revealed at least 10 such organisms, some of which are similar to those found in man. Similar studies with poultry also yielded a number of new varieties, some of which are quite common in man.

At the Kansas station conclusive evidence has been secured to show that the tapeworms which gain entrance to the intestines of young chickens are able to remain there after the host matures. Studies of the transmission of the large roundworm (*Ascaridia perspicillum*) show that infection is direct, no intermediate insect or invertebrate being necessary for transmission. The eggs of this parasite pass out with the feces and in two weeks of warm moist conditions attain the infective stage. When such eggs are swallowed by young chicks they become infected. The common housefly is found capable of transmitting two tapeworms, *Davainea cesticillus* and *D. tetragona.*

Experiments at the Minnesota station show that the chick nematode (*Heterakis papillosa*) does not, like Ascaris, pass a part of its early cycle in the lung of the host. Its development is simple and direct, the worms maturing in about a month. None of the recommended disinfectants will render infected ground safe. The eggs will develop to the infective stage in a 1:1,000 solution of mercuric chlorid or in a 1 per cent solution of sulphuric acid. Thorough sanitation is essential and internal treatment of the birds with 1 part chloroform to 20 parts turpentine gave good results.

The Oklahoma station has secured evidence which seems to indicate that if the eggs of the roundworm passed from an infected bird are taken by another they will pass through without hatching. In order to infect they must develop larvæ in the ground, which requires from 10 days to several weeks, depending upon the temperature. Chicks fed the larvæ all died of pneumonia in from 8 to 10 days.

Poisonous plants.

The study of poisonous plants of pastures and ranges has received considerable attention, especially from the stations in the West. At the Wyoming station sheep were put on a patch of the two-grooved milk vetch (*Astragalus bisulcatus*), which is reported to be poisonous, for 50 days with no harmful results. Cattle refused to eat it. It was found that the aconites play a larger rôle in forage poisoning than formerly supposed, causing heavy losses in sheep. It is believed that the toxic principle of the low larkspur (*Delphinium menziesii*) has been isolated. It gives the same kind of alkaloid as the tall larkspur, but not in such large amounts, although it is claimed to be equally as poisonous, the maximum toxicity apparently being in the flowering stage. It is not poisonous to sheep, but is to cattle, of which it is estimated that there was a loss of 60,000 due to poisoning by this plant during the year. Successful antidotes have been prepared. The station has isolated two crystalline alkaloids from a lupine (*Lupinus argenteus*), one of them apparently new. The plant affects sheep mainly. There is no known remedy. The Nevada station, however, reports that all parts of the lupine, at all stages of growth, were fed to sheep without injurious effect. Alcoholic extracts of the milkwort (*Glaux maritima*) were toxic to rabbits, but both the green and cured plants fed to cattle and sheep produced no injurious results at the Wyoming station.

The Montana station finds that white loco, the only poisonous variety, averaged 12,000 to 15,000 plants per acre. One man can clear an acre a day, and the plants do not return.

A study of the toxicity of poisonous range plants, by the Nevada station, showed that quite small amounts of rabbit brush (*Tetradymia glabrata*) fed consecutively for several days has a cumulative effect and finally causes the death of sheep. *Atriplex canescens* and *A. confertifolia* were found to be slowly injurious rather than immediately poisonous, causing polyuria and diarrhea, with a falling off in weight. *A. canescens*, fed in large doses to ewes immediately before lambing, caused abortion. *Halerpestes cymbalaria* contains an irritant poison which may be fatal under certain conditions to both sheep and cattle. *Artemisia spinescens* was negative to both sheep and cattle, as were all local species of lupines.

Arrow grass (*Triglochin maritima*) was found to contain a hydrocyanic glucosid, of which the dried plant yielded 0.25 per cent of its weight. Feeding experiments with the shad scale (*Atriplex canescens*) showed that while it has no toxic effect on cattle it does act injuriously on sheep, causing extreme diarrhea and urination with loss of weight. Analysis shows it to have a high feeding value, but also that it contains two saponins that may be the cause of its injurious action with sheep. It is noted that the poisonous action of many plants appears to vary from year to year, from unknown causes. Their action also varies largely with different animals. Ground squirrels feed extensively on death camas without apparent injury. With the poison hemlock, early growth of the tops was found to be as toxic as the tuberous roots, while late in the season the tops were apparently not toxic. Two species of milkweed, *Asclepias mexicana* and *A. speciosa*, were found to be poisonous.

At the Colorado station the whorled milkweed (*Asclepias galioides*) was found to contain a glucosid and an alkaloid that have not been obtained pure as yet. The plants lost their toxicity with prolonged drying, and after six months it had nearly disappeared. Most of the active principle was found in the leaves, with but little in the stems and flowers. Crude extracts of the dried powdered plant were fatal to guinea pigs, but the partially purified product was not.

At the Mississippi station 5 cubic centimeters of the oil of ergot of Paspalum was fatal to guinea pigs, and the fatty acids derived from it were also toxic. It contains no nitrogen and does not lose its poisonous properties when heated to 200° F.

At the Kansas station a comparison of the trouble known as "corn stalk disease," with anthrax, botulism, hemorrhagic septicemia, and potash poisoning led to the conclusion that it is a definite disease, although the exact cause has not as yet been determined.

AGRICULTURAL ENGINEERING.

Implements and machines.

In tractor tests at the Mississippi station hay was cut on a 9-acre area at a cost of 41 cents per acre, and loaded, without windrowing, at 55 cents per acre.

Investigation at the Missouri station shows that while the draft of plows is materially decreased by disking before plowing, the total amount of work done by disking first is greater than in plowing without disking, in spite of the fact that the draft is greater. Studies at the Iowa station show that the type of bottom on the plow does not materially influence draft. The increase in draft due to speed, which is from less than one-third to about one-half the total draft, within a speed of from 2 to 4 miles per hour, is confined to the draft required for turning and pulverizing. A marsh plow has been devised by the Wisconsin station, using a larger coulter, a heavier frame, a stronger wheel, and longer and higher landslide, which will go through almost any amount of trash and sod without clogging, turning the furrows directly upside down, and practically completely covering the trash and leaving the furrow slices lying flat, in condition for working the seed bed.

At the Iowa station a comparison of round and cutaway harrow blades shows that the latter give a 10 to 20 per cent heavier draft, penetrate more deeply, tend to tear out chunks rather than loosen the surface, are difficult to sharpen, and more easily broken.

A test of limestone spreaders indicated that the most desirable type was that of a trailer behind a loaded wagon, from which the material is shoveled direct to the spreader.

In stump-pulling tests by the Wisconsin station a pull of 20,000 pounds was found to be about the safe limit for a ¾-inch cable, and under most conditions the pieces pulled at this limit were as large as could be economically handled and piled. Experiments with picric acid for land clearing showed it to be much more powerful for stump blasting than any of the ordinary dynamites used, and that 5.5 to 6 ounce cartridges are as effective as 8-ounce cartridges of 20 to 40 per cent dynamite. A 2 per cent moisture content allays dust in cartridges, and with this amount the charges can be de-

tonated with a No. 8 cap. The picric acid is more shattering than low-grade dynamite. It is not affected by temperature, does not freeze, is more resistant to moisture than dynamite containing ammonium nitrate, does not detonate in storage, and is not poisonous.

Fence-post treatment.

Tests at the Minnesota station show that there is little difference between the life of treated and untreated Jack pine fence posts. Treated poplar posts are found to outlast treated Jack pine posts. The Iowa station has demonstrated that quick growing, nondurable Iowa woods can be successfully used for fence posts after having been treated with creosote. For the successful treating of willow posts it is necessary to treat the tops as well as the bottoms. One-fourth inch square twisted rods proved best for reinforcing concrete fence posts, and when these are placed about three-fourths inch from the surface they give the greatest strength.

Silo walls.

For treating silo walls a plastic bitumen material, protected by plaster, gave the best results at the Minnesota station.

Retention of irrigation water.

Studies in soil moisture at the Oregon station show that the coarsest irrigated soil retains about one-half inch of usable water to the acre-foot, heavy silty clay loam about 2 inches, fine sand 1 inch, and sandy loam 1½ inches. The duty of water for alfalfa was not less than 5¼ to 6 inches per ton.

SUGAR MAKING.

At the Louisiana station investigations on the clarification of cane juices indicate that there is little advantage in removing the sulphur precipitate from raw cane juice before liming. The use of suitable dyestuffs as indicators in the control of the sulphitation process, to determine the end point of sulphitation and liming, was found to be satisfactory and much less time-consuming than titration. No means have been found to prevent the formation of the precipitate when clarified cane juice is evaporated to sirup, which appears to result from flocculation of colloidal matter, natural to the juice, regardless of treatment. It is found that carbons decolorize better if the juice is acid, but the time of acidifying and decolorizing should be made as short as possible to prevent inversion.

Deterioration of cane sugar was found not to occur in the outer exposed parts of the bags, bacteria being more numerous in the center. By the use of superheated steam in the centrifugals it was possible to reduce the number of organisms over 90 per cent, thereby eliminating one of the most important factors in sugar and molasses deterioration. As most of the bacteria apparently go out of the centrifugal into the molasses, in order to sterilize both the sugar and the molasses the steam must be turned on when the centrifugal is started. Most of the infection is due to wash water and air currents.

RURAL ECONOMICS.

Partly through the efforts of the California station a State land settlement board has been created by the legislature, the settlements

under which have demonstrated the practicability of a credit system based on the character of the borrower, long-time amortized payments on land, community action in the improvement of live stock, cooperation in the purchase of equipment and the selling of products, and the effecting of better living conditions in rural communities.

An extensive survey by the Indiana station showed that the successful farms studied owe their success to a large farm business, efficient use of man and horse labor, more live stock, better live stock, and large crop yields.

The Mississippi station found the largest labor incomes to be on farms having 16 per cent in cotton, 12 per cent in corn, and 26.5 per cent in oats. Corn and hogs were not profitable. The Utah station reports that farmers with only a grade schooling made an average labor income of $446, those who had attended high school made $805, and those of more than a high-school education made $2,770.

From data secured by the Missouri station it is shown that approximately 80 per cent more man labor and 40 per cent more horse labor is required to grow an acre of corn on fields under 10 acres in size than on fields of more than 30 acres.

The Missouri station finds that the 1920 wheat crop cost the Missouri farmer $2.26 a bushel to produce, the oat crop $0.82 a bushel, and the corn crop $1.01 a bushel. Figures obtained by the Washington station show that the average cost of producing winter wheat in 1919 was $1.63 per bushel on owned land and $1.54 on tenant farms, ranging from $0.70 to $4 per bushel. Spring wheat ranged from $0.80 to $4. The data secured indicated a material reduction in the cost of producing wheat where peas were grown on the summer fallow.

Studies at the Indiana station on the cost of producing beef show that feed constitutes 70 to 85 per cent of all expenses other than the initial cost of the animals. Man and horse labor constitute 5 to 7 per cent, depreciation and upkeep of buildings and fences 5 to 6 per cent, interest on investment 3 to 4 per cent, marketing costs 2 per cent, and death-risk insurance and taxes 2 to 4 per cent. Credit for pork and manure approximate all the costs other than feed when corn is fed in the ration.

INSULAR EXPERIMENT STATIONS.

The work and expenditures of the experiment stations located in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands are published as separate reports. The Office of Experiment Stations exercises general supervision over these stations, which derive their support from direct Federal appropriation to the Department of Agriculture. They are under the immediate charge of W. H. Evans.

VISITATION OF THE STATIONS.

Each of the continental stations receiving Federal funds was visited by a representative of the office during the year for an examination of the work and expenditures, presenting also an opportunity to confer with the station officers in regard to organization and administration. These examinations were made by the chief (E. W. Allen), W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte.

These visits, with the extensive correspondence during the year, the careful review and approval of the projects carried on under the Adams fund, and the examination of the financial reports at the close of the year, before they are formally approved, serve to keep the office in close touch with the work and administration of these institutions.

STATISTICS OF THE STATIONS.

For the fiscal year ended June 30, 1921, the total income reported by the experiment stations from all sources was $7,660,570.77. This amount includes $1,440,000 derived from Federal sources under the Hatch and Adams Acts and $210,000 appropriated by the Federal Government for the experiment stations in Alaska and the insular possessions.

The support of the stations from within the States included $3,786,997.94 derived from State appropriations or apportionments, $359,964.92 from fees, $1,167,856.62 from the sale of farm and other products, $371,421.86 from miscellaneous sources, and $534,329.43 carried over as balances from the previous year. As the State fiscal year does not in all cases coincide with that of the Federal Government, and as unexpended balances on State appropriations are usually permitted to be carried forward to the succeeding year, the above amounts were not fully expended, but portions were carried over to the fiscal year 1922. The amount of this carry over there are no data for estimating at the present time.

The resources as stated above, which come from within the State, can not be accepted at absolutely face value, but need interpretation. In a considerable number of the States the experiment station has no budget of its own or specific appropriation for its use. Fully a third of the stations receive their State aid through an allotment made by the college authorities from the general appropriation of the college. Sometimes this is a definite amount, set apart for the use of the station, and in others it is allotted in connection with the general support of college departments without specifying the proportion or amount to be devoted to the station. Where no account is kept of the expenditures on account of the station work, the returns are largely an estimate, based on the percentage of the entire fund of the college or on the judgment of administrative officers. Some institutions make a very careful estimate based on an analysis of individual department expenditures, while others can only attempt an approximation, which there are evidences may not be very accurate for a given year. This makes it very difficult to compile statistics of State revenues which are accurate, although efforts are made from year to year to check up the revenues as reported and to secure as close an approximation as possible. Furthermore, these State funds often cover the appropriations for inspections and regulatory work of a wide variety.

The proceeds from sales constitute another item which is subject to interpretation. In individual cases these may include the sales from the entire college farm, or from parts in which the experiment station is not concerned. The item is swelled by commercial enterprises outside the range of the station proper and in the proceeds

from which it only profits quite incidentally. It can not be assumed, therefore, that the aggregate amount of the sales fund is station revenue or is available for carrying on the station investigations. It fluctuates from year to year, and in institutions like the colleges and stations it is likely to represent a net expense or at most a turnover. If it were possible to estimate accurately the revenues at the disposal of the stations for the activities lying within their specific field, it is believed that the total amount would shrink quite materially.

During the year the stations added to their buildings and equipment to the extent of nearly a million dollars. These additions are classified as follows:

Buildings	$459, 644. 38
Library	29, 023. 53
Apparatus	67, 598. 63
Farm implements	107, 490. 62
Live stock	147, 229. 36
Miscellaneous	181, 321. 51
Total	992, 308. 03

In the work of administration and inquiry the experiment stations employed 1,965 persons. Of these, 1,023 were also members of the teaching staffs of the colleges and 434 assisted in the various lines of extension work.

During the year the stations issued 830 publications, including annual reports, bulletins, circulars, press bulletins, etc., aggregating 20,148 pages. These were distributed to nearly 900,000 addresses on regular mailing lists, in addition to the numbers sent in response to special requests, which show constant increase.

The statistics of the stations by States are given in detail in the following tables:

General statistics, 1921.

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in extension work.	Publications during fiscal year 1920–21. Number.	Publications during fiscal year 1920–21. Pages.	Number of names on mailing list.
Alabama (College)	Auburn	J. F. Duggar	Feb. —, 1883	Feb. 24, 1888	22	9	6	4	108	20,000
Alabama (Canebrake)	Uniontown	J. M. Burgess	Jan. 1, 1886	Apr. 1, 1888	...	...	...	...	...	...
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897	...	5	4	...	...	...	...
Alaska	Sitka	C. C. Georgeson	...	...	9	...	...	2	194	4,200
Arizona	Tucson	D. W. Working	...	——, 1889	23	16	5	15	302	8,500
Arkansas	Fayetteville	Bradford Knapp	...	——, 1887	21	21	6	3	83	10,000
California	Berkeley	C. M. Haring	——, 1875	Mar. —, 1888	120	78	60	36	1,095	39,300
Colorado	Fort Collins	C. P. Gillette	...	Feb. 29, 1888	40	9	9	13	491	2,800
Connecticut (State)	New Haven	E. H. Jenkins	Oct. 1, 1875	May 18, 1887	19	1	...	6	406	9,800
Connecticut (Storrs)	Storrs	do	...	do	12	6	8	2	48	7,000
Delaware	Newark	C. A. McCue	...	Feb. 21, 1888	14	9	3	3	126	9,000
Florida	Gainesville	Wilmon Newell	...	——, 1888	12	...	7	8	58	18,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	6	...	...	41	50	6,000
Guam	Guam	C. W. Edwards	...	...	4	...	...	2	62	2,909
Hawaii	Honolulu	J. M. Westgate	...	...	6	...	6	1	73	2,427
Idaho	Moscow	E. J. Iddings	...	Feb. 26, 1892	39	18	18	20	172	11,000
Illinois	Urbana	Eugene Davenport	...	Mar. 21, 1888	78	67	20	12	228	42,000
Indiana	Lafayette	G. I. Christie	——, 1885	Jan. —, 1888	61	18	6	16	740	38,124
Iowa	Ames	C. F. Curtiss	...	Feb. 17, 1888	71	22	10	20	736	33,000
Kansas	Manhattan	F. D. Farrell	...	Feb. 8, 1888	75	30	...	12	603	12,500
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	55	20	10	7	308	20,000
Louisiana (Sugar)	New Orleans	...	Sept. —, 1885	} ...	} 23	} 3	} 9	} 9	} 340	} 19,000
Louisiana (State)	Baton Rouge	W. H. Dalrymple	Apr. —, 1886							
Louisiana (North)	Calhoun	...	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	17	...	...	37	629	20,950
Maryland	College Park	H. J. Patterson	——, 1888	Apr. —, 1888	30	19	...	8	194	20,000
Massachusetts	Amherst [1]	S. B. Haskell	——, 1882	Mar. 2, 1888	47	7	1	23	452	21,663
Michigan	East Lansing	R. S. Shaw	...	Feb. 26, 1888	66	51	20	19	896	45.000
Minnesota	University farm, St. Paul	R. W. Thatcher	Mar. 7, 1885	——, 1888	85	68	50	8	683	11,000
Mississippi	Agricultural College	J. R. Ricks	...	Jan. 27, 1888	30	20	...	19	285	13,000
Missouri (College)	Columbia	F. B. Mumford	...	Jan. —, 1888	45	45	...	87	1,347	6,368
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900	...	4	...	...	...	...	...
Montana	Bozeman	F. B. Linfield	...	July 1, 1893	28	15	...	15	314	11,00
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	38	32	2	9	224	8,500
Nevada	Reno	S. B. Doten	...	Dec. —, 1887	8	3	1	3	70	6,000
New Hampshire	Durham	J. C. Kendall	——, 1886	Aug. 4, 1887	20	14	15	7	151	22,000
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880	...	42 }	20	39	53	1,750	17,000
New Jersey (College)	do	do	...	Apr. 26, 1888	17 }					

[1] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch Station at the same place.

General statistics, 1921—Continued.

Station.	Location.	Director.	Date of original organization.	Date of organization under Hatch Act.	Number on staff.	Number of teachers on staff.	Number of persons on staff who assist in extension work.	Publications during fiscal year 1920–21.		Number of names on mailing list.
								Number.	Pages.	
New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	17	13	7	34	318	10,000
New York (State)	Geneva	W. H. Jordan	Mar. —, 1882		41			17	447	47,756
New York (Cornell)	Ithaca	A. R. Mann	——, 1879	Apr. —, 1888	60	60	11	4	337	2,869
North Carolina (College)	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	45	4	3	3	112	4,950
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	31	10	3	12	338	8,841
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	54			65	696	71,597
Oklahoma	Stillwater	H. G. Knight		Dec. 25, 1890	22	19		6	128	5,340
Oregon	Corvallis	J. T. Jardine		July —, 1888	55	30		14	732	1,064
Pennsylvania	State College	R. L. Watts		June 30, 1887	69	68	69	6	164	40,800
Pennsylvania (Nutrition)	do	H. P. Armsby	——, 1907		8					500
Porto Rico	Mayaguez	D. W. May			9		1	6	157	3,400
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	12	3		6	126	1,850
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	23	7	6	5	240	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	15	16		5	137	2,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	18	1		8	138	12,100
Texas	College Station	B. Youngblood		Apr. 3, 1889	46	1		26	1,136	55,000
Utah	Logan	F. S. Harris		——, 1890	37	36	14	9	392	10,000
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	12	9	2	2	72	2,500
Virginia	Blacksburg	A. W. Drinkard, jr	——, 1888	——, 1891	25	11		8	234	11,000
Virginia (Truck)	Norfolk	T. C. Johnson			7			3	69	6,500
Virgin Islands	St. Croix	L. Smith			2		2	3	65	500
Washington	Pullman	E. C. Johnson		——, 1891	40	12		9	298	14,605
West Virginia	Morgantown	J. L. Coulter		June 11, 1888	32	25	4	31	346	20,000
Wisconsin	Madison	H. L. Russell	——, 1883	——, 1887	87	63	40	23	752	46,875
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	16	10	1	5	166	6,000
Total					1,965	1,023	434	830	20,148	899,079

Revenue and additions to equipment, 1921.

Station.	Federal.		State.	Balances from previous year.[1]	Fees.	Sales.	Miscellaneous.	Total.	Additions to equipment.						
	Hatch fund.	Adams fund.							Buildings.	Library.	Apparatus.	Farm implements.	Live stock.	Miscellaneous.	Total.
Alabama (College)	$15,000.00	$15,000.00	$3[illegible],500.00	$7,118.69		$2,718.72		$7[illegible],337.41			$950.00	$205.00		$350.00	$1,505.00
Alaska [2]							$75,000.00	75,000.00							
Arizona	15,000.00	15,000.00	49,[illegible]81.97	13,451.90		11,776.28		104,510.15	$19,699.0[illegible]	$7.87	444.58	1,009.0[illegible]	$1,847.75	295.20	23,303.48
Arkansas	15,000.00	15,000.00	43,07[illegible].67			10,[illegible]8[illegible].88		83,359.55	781.81	1,146.04	2,044.58	1,130.24	2,094.84	45,503.34	52,700.85
California [3]	15,000.00	15,000.00	1[illegible]7,378.71	374.04	$3,583.39	62,069.10	40,921.87	28[illegible],327.11	30,241.90	2,811.86	5,4[illegible]5.30	15,311.80	5,205.54	2,343.08	61,359.48
Colorado	15,000.00	15,000.00	75,329.33	49,683.66				155,012.99	6,129.87	411.78	7,036.96	1,039.91	6,793.52	19,938.07	41,350.11
Connecticut (State)	7,500.00	7,500.00	38,200.00	13.45	17,000.00		12,792.87	83,006.32	30.00	495.03	154.15	552.66	57.50	437.79	1,727.13
Connecticut (Storrs)	7,500.00	7,500.00	27,821.74				18,881.60	61,703.34		31.74		360.00	1,084.00		1,475.74
Delaware	15,000.00	15,000.00	10,000.00			14,799.35		54,799.35		281.73	1,260.07	2,48[illegible].1[illegible]	3,263.48		7,289.42
Florida	15,000.00	15,000.00	5,000.00	3,979.94		5,891.83	3,782.15	48,653.92	310.11	599.10	53[illegible].58	171.02		236.17	1,850.98
Georgia	15,000.00	15,000.00	51.08	5,161.32		6,207.97		41,420.37	1,261.49	283.53	81.1[illegible]	312.10	1,269.83	35,136.60	38,344.69
Guam [2]							15,000.00	15,000.00							
Hawaii [2]							50,000.00	50,000.00		453.6[illegible]	238.00	1,051.42	500.00	248.67	2,491.73
Idaho	15,000.00	15,000.00	21,257.38	768.48		2,389.49		5[illegible],[illegible]15.35	1,200.00	90.00	1,550.00	1,000.00	3,000.00	1,400.00	8,2[illegible]0.00
Illinois	15,000.00	15,000.00	140,000.00	15,633.54		98,617.48		28[illegible],251.02	51.81		3,117.78	3,210.34	3,044.04		9,423.97
Indiana	15,000.00	15,000.00	150,232.87	70,344.32	98,638.19	110,384.74		[illegible]59,600.12	32,389.08	1,010.16	800.06	4,766.34	19,113.91	3,785.02	61,86[illegible].57
Iowa	15,000.00	15,000.00	140,500.00	66,980.05		37,051.61	29.25	274,560.91	7[illegible],877.5[illegible]		1,01[illegible].04	4,432.16	5,551.44	781.88	86,657.16
Kansas	15,000.00	15,000.00	82,000.00	22,000.22		60,932.68		19[illegible],932.90	1,000.00	25.00	597.03	922.20	3,096.50		5,640.73
Kentucky	15,000.00	15,000.00	50,000.00	75,295.77	96,589.32	53,484.43		305,369.52	4,131.61	415.36	970.86	400.00	1,565.00	1,530.38	9,013.21
Louisiana	15,000.00	15,000.00	49,999.96	434.76		9,035.04	1,766.87	91,236.63	832.87	417.97	2,031.88	3,911.24	1,143.20	5,292.93	13,630.09
Maine	15,000.00	15,000.00	15,000.00		12,486.65	25,091.5[illegible]	17,862.72	100,440.91	13,019.29	851.59	287.33	2,493.27	1,621.07	491.25	18,763.80
Maryland	15,000.00	15,000.00	5[illegible],028.02			18,432.99		102,461.01		401.89	712.01	4,984.91	369.42	795.63	7,263.86
Massachusetts	14,000.00	15,000.00	83,[illegible]00.00		15,025.88	10,128.13	343.56	138,767.57	914.80	691.98	375.96	978.46	1,143.00	167.16	4,271.36
Michigan	15,000.00	15,000.00	197,013.29		25,420.00	7,637.[illegible]3	5,968.87	266,039.39	18,959.43	641.54	1,561.22	4,242.94	3,369.04		28,774.17
Minnesota	15,000.00	15,000.00	219,000.00			80,579.38	3,092.30	332,671.68	17,568.77	1,678.09	2,524.87	5,289.26	15,987.88	3,222.22	46,271.09
Mississippi	15,000.00	15,000.00	94,829.53	16,359.56	90.00	7,485.19	423.22	149,187.50	37,350.00	349.08	493.68	5,014.25	2,624.50	3,342.30	49,173.81
Missouri (College)	15,000.00	15,000.00	35,[illegible]01.33	12,047.10	30,165.82	14,420.04		121,834.29	2,632.12	389.63	1,810.40	442.13	4,951.17	868.40	11,093.85
Montana	15,000.00	15,000.00	79,395.51			18,863.89		128,259.40		230.00	1,030.00	3,500.00	150.00		4,910.00
Nebraska	15,000.00	15,000.00	51,723.55	30,320.09		73,499.98		185,5[illegible]3.62		2,250.00	862.95	882.46	855.18		4,850.59
Nevada	15,000.00	15,000.00	140.87	244.09		941.63		31,3[illegible]6.59	964.17	117.36	37.58	861.15	1,694.60	68.80	3,743.66
New Hampshire	15,000.00	15,000.00		1,315.11		2,651.78	15,970.42	49,940.31		350.00	2,109.92	35.00	150.00	367.20	3,012.12
New Jersey (State)			119,162.64		50,032.42	36,608.01		205,803.07							

[1] Not including balances from Federal funds.
[2] Federal appropriations.
[3] The resources from other than Federal funds are estimated.

Revenue and additions to equipment, 1921—Continued.

Station.	Federal.		State.	Balances from previous year.[1]	Fees.	Sales.	Miscellaneous.	Total.	Additions to equipment.						
	Hatch fund.	Adams fund.							Buildings.	Library.	Apparatus.	Farm implements.	Live stock.	Miscellaneous.	Total.
New Jersey (College)[2]	$15,000.00	$15,000.00						$30,000.00	$75,000.00	$700.00	$500.00	$500.00	$2,000.00		$78,700.00
New Mexico	15,000.00	15,000.00	$7,500.00	$14,007.65		$7,133.92		58,641.57	415.51	8.33	306.27	662.63	95.00	$149.02	1,636.76
New York (State)[2]	1,500.00	1,500.00	185,829.22	5,005.45				193,834.67		930.00	1,200.00				2,130.00
New York (Cornell)	13,500.00	13,500.00	192,629.81		$10,863.25	27,362.40	$10,351.57	268,207.03	6,919.09	897.52	2,937.87	3,864.67	206.29	3,927.19	18,752.63
North Carolina (College)	15,000.00	15,000.00	103,550.00			3,532.46	3,750.00	140,832.46	3,500.00	212.62	70.00	297.11			4,079.73
North Dakota	15,000.00	15,000.00	103,108.90			53,771.29	6,825.00	193,705.19	2,500.00	82.85	1,265.73	4,730.65	9,579.55	738.87	18,897.65
Ohio	15,000.00	15,000.00	265,365.00	58,430.39		43,571.88		397,367.27	28,265.53	1,001.86	1,538.43	942.10	1,030.25		32,778.17
Oklahoma	15,000.00	15,000.00	10,000.00	1,655.88		7,595.85		49,251.73	400.50	964.71	219.19	607.85	2,926.43	271.92	5,390.60
Oregon	15,000.00	15,000.00	92,750.00	8,866.30		42,505.42	4,000.00	178,121.72		20.00	1,229.33	2,159.97	7,385.54	2,750.36	13,545.20
Pennsylvania	15,000.00	15,000.00		3,669.43				33,669.43		202.24	719.45	2,900.14	2,400.00		6,221.83
Porto Rico[3]							50,000.00	50,000.00	2,224.11	108.24	228.35	354.97	160.00	15.56	3,091.23
Rhode Island	15,000.00	15,000.00	1,693.29	684.37		7,863.05		40,240.71		259.81	357.00	401.45	92.00	2.50	1,112.76
South Carolina	15,000.00	15,000.00	50,000.00	2,219.43		13,840.63	5,467.55	101,527.61	11,000.00	1,321.35	1,173.79	1,443.73	4,661.00		19,599.87
South Dakota	15,000.00	15,000.00	14,460.00	7,009.45		1,399.26	8,198.39	61,067.10			900.00	850.00		325.00	2,075.00
Tennessee	15,000.00	15,000.00	31,904.27			647.23		62,551.50		600.34	231.52	2,951.02	3,065.62	423.25	7,271.75
Texas	15,000.00	15,000.00	220,519.17	4,517.30		56,772.08		311,808.55	21,249.51	525.04	5,045.38	5,368.88	5,166.11	9,885.16	47,240.08
Utah	15,000.00	15,000.00	53,468.29	8,272.21		28,837.23		120,577.73	2,000.00	900.00	3,000.00	500.00	1,000.00	7,125.00	14,525.00
Vermont	15,000.00	15,000.00						30,000.00	488.79	152.30	966.40	39.80	425.00		2,072.29
Virginia	15,000.00	15,000.00	38,350.00	6,276.78		12,341.87	993.65	87,962.30	1,102.43	398.72	386.03	1,211.94		46.13	3,145.25
Virgin Islands[3]							20,000.00	20,000.00	1,276.97	36.79	128.00	286.00		13.64	1,741.40
Washington	15,000.00	15,000.00	87,760.47	18,730.51		42,864.90		179,355.88	18,020.09	647.59	1,011.75	2,424.33	6,146.38	1,442.63	29,692.77
West Virginia	15,000.00	15,000.00	104,787.07	2,749.97		30,119.46		167,656.50	20,600.00	338.42	591.76	1,309.92	3,802.56	25,147.58	51,790.24
Wisconsin	15,000.00	15,000.00	210,000.00					240,000.00		929.10	2,423.77	2,382.16	3,984.26	1,662.03	11,381.32
Wyoming	15,000.00	15,000.00		708.22		5,711.30		36,419.52	336.14	1,353.73	1,091.68	307.86	1,556.96	793.48	5,439.85
Total	720,000.00	720,000.00	3,786,997.94	534,329.43	359,964.92	1,167,856.62	371,421.86	7,660,570.77	459,644.38	29,023.53	67,598.63	107,490.62	147,229.36	181,321.51	992,308.03

[1] Not including balances from Federal funds.
[2] Including balances from previous year: $0.51 Hatch and $34.78 Adams (New York State Station); $166.72 Adams (New Jersey).
[3] Federal appropriations.

Expenditures from United States appropriations received under the

Station.	Amount of appropriation.	Classified expenditures.						
		Salaries.	Labor.	Publications.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.
Alabama	$15,000.00	$7,852.51	$2,652.36	$486.02	$894.17	$170.03	$117.63	$99.95
Arizona	15,000.00	13,248.73	65.12		76.10	18.67		93.64
Arkansas	15,000.00	8,070.00	1,394.18	135.13	206.96	255.20	103.19	178.70
California	15,000.00	15,000.00						
Colorado	15,000.00	10,996.83	1,272.68	695.35	302.40	5.40		94.70
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	8,103.31	2,544.57	1,486.13	718.71	27.06	331.44	68.81
Florida	15,000.00	8,697.50	2,147.53	812.33	758.30	347.79	343.25	12.45
Georgia	15,000.00	8,024.93	3,660.61	629.82	312.92	145.31	571.61	33.22
Idaho	15,000.00	10,757.19	1,884.29		17.86	67.73	38.75	527.41
Illinois	15,000.00	14,842.37	157.63					
Indiana	15,000.00	13,408.32	1,273.98		5.46			84.69
Iowa	15,000.00	8,396.35	1,257.94	757.67	1,137.29	46.44	336.55	11.75
Kansas	15,000.00	8,898.34	5,262.07	10.30	239.54		12.00	7.55
Kentucky	15,000.00	14,975.00						
Louisiana	15,000.00	7,970.75	3,232.10	833.60	72.21	10.10	195.53	
Maine	15,000.00	8,387.12	1,368.44	159.93	390.89	71.89	615.16	8.00
Maryland	15,000.00	12,182.49	826.35	412.00	3.49		178.27	55.23
Massachusetts	15,000.00	14,902.50	97.50					
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,587.55	3,874.23		39.74	32.28	382.16	
Missouri	15,000.00	9,315.59	2,837.38	198.81	128.23	195.57	65.84	100.20
Montana	15,000.00	12,507.87	661.86		145.47	66.49	75.37	52.33
Nebraska	15,000.00	7,299.40	2,942.78	1,495.85	112.20	23.96		192.04
Nevada	15,000.00	8,417.15	2,201.00	650.39	263.91	119.62	156.20	1.25
New Hampshire	15,000.00	9,451.85	983.85	1,263.16	533.30	349.75	600.00	65.16
New Jersey	15,000.00	9,162.93	1,303.11	504.98	265.27	40.20	91.22	907.81
New Mexico	15,000.00	4,762.75	3,544.08	2,738.09	85.16	154.18	134.52	151.88
New York (State)[1]	1,500.00	150.00	1,020.00		69.85	35.62		
New York (Cornell)	13,500.00	9,285.00	2,510.89		14.27		11.45	751.00
North Carolina	15,000.00	11,863.84	3,136.16					
North Dakota	15,000.00	14,930.45						69.55
Ohio	15,000.00	6,964.76	4,481.44		116.19	1,337.02		67.01
Oklahoma	15,000.00	8,256.62	1,992.80	733.75	269.37		67.41	434.57
Oregon	15,000.00	12,480.66	535.73	1,274.61	40.18	63.18		1.40
Pennsylvania	15,000.00	11,316.29	510.66	1,477.11	106.86	89.99	31.44	242.33
Rhode Island	15,000.00	5,774.28	4,094.97	1,619.52	108.37	167.18	54.61	71.58
South Carolina	15,000.00	7,290.72	3,423.30	365.62	749.78	260.74	22.50	24.58
South Dakota	15,000.00	9,939.91	2,510.20	1,146.90	36.16	.44		605.46
Tennessee	15,000.00	10,265.72	871.86	1,187.50	411.95	44.69	746.70	1.91
Texas	15,000.00	10,883.22	2,323.07		608.09	20.08		202.73
Utah	15,000.00	10,389.26	2,436.49		120.83	100.26	275.95	355.98
Vermont	15,000.00	6,809.16	1,593.12	3,126.74	167.66	27.09	1,238.50	161.03
Virginia	15,000.00	9,618.26	2,849.12	316.09	222.10	87.52	528.97	76.72
Washington	15,000.00	8,667.82	3,277.87	1,600.79	71.06			5.40
West Virginia	15,000.00	12,122.60	702.22	564.40	8.00	24.63		152.25
Wisconsin	15,000.00	8,600.00	2,573.75	458.36	19.34	1.97		841.34
Wyoming	15,000.00	11,381.25	80.25	363.75		1.77	40.39	161.27
Total	720,000.00	497,209.15	88,369.54	27,504.70	9,849.64	4,409.85	7,366.61	6,972.88

[1] Including a balance of $0.51.

act of March 2, 1887 (Hatch Act), for the year ended June 30, 1921.

Classified expenditures.											
Seeds, plants, and sundry supplies.	Fertilizers.	Feeding stuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Buildings and repairs.	Balances.
$388.58		$231.30	$574.73	$241.65	$718.04	$16.84		$280.57		$275.62	
56.90			5.00		53.40	366.42	$800.00	130.71		85.31	
1,180.05	$200.12	993.90	4.50	1,082.80	118.46	172.18	612.04	286.34		6.25	
178.45		212.98	44.83	46.50	63.40	232.55	189.60	293.83		370.50	
433.58	147.00		232.17	65.65	345.25	60.02		431.35	$4.95		
76.52	8.12	823.20	531.43	196.37	100.92			115.34	10.15	18.80	
601.49	296.80	50.40	211.71	207.03	20.55	.94	39.00	180.43		13.23	
245.32		571.75	10.60	119.00	84.00	58.74		603.31	5.00	9.05	
3.93		199.45						24.17			
600.47	26.02	1,737.47		124.55	13.77	265.00		283.40	5.33		
269.38				194.16				51.86		54.80	
		25.00									
270.67	551.05	737.88	17.00	178.08	20.00			185.00		726.03	
246.80	333.16	2,460.05	190.26	339.34	42.25	29.01		315.93	25.62	16.15	
489.56			5.50	32.11	599.25	158.35				57.40	
274.71	100.18	709.15									
353.53		1,067.57		14.84	8.01	26.33	253.95	116.04		318.11	
166.50	6.30	148.25	54.38	25.95	473.30	88.11		527.82			
343.82		1,315.44	21.40	511.65	357.25	180.71	11.00	192.50			
394.68		425.20	53.57	787.87	66.30	35.08	105.75	774.40		547.63	
250.22	44.45		361.45	17.29	325.00	59.39		687.57		7.56	
610.64	8.30		82.69	60.62	104.15	34.58		1,683.32	10.20	129.98	
242.53	81.61	2,642.54		37.33	48.61		25.00	324.22		27.50	
98.21			7.00			75.94		35.54			$7.84
432.70	60.80			139.18	20.81	255.70		18.20			
240.74	449.49	197.49	56.35	163.60		353.18				572.73	
360.42		1,506.67	462.50	380.80	102.95	4.13	67.20	298.81		62.00	
27.97				101.90		289.89		184.48			
366.90	258.12		28.09	23.99	9.24	46.69		344.03		148.26	
279.68	1,434.66	519.05	345.55	97.73	2.10	54.45		113.33		262.94	
353.71		1,295.81	479.75	264.79	201.79			175.32		91.59	
272.58		28.65	6.80	128.00	8.80	142.00	90.00			84.10	
75.16	26.75		515.81	53.28	108.25	5.25		217.69		467.48	
130.14	6.00	3.50	25.10	82.12	263.81		152.29			299.85	
552.13			170.65	129.14	28.27	18.10		388.76		34.18	
636.30	83.81	224.10	136.84	38.93	55.99	477.46		140.38		82.89	
332.64	153.55	36.00	379.88	230.43	3.16	10.59	2.00	85.24		67.73	
467.71	9.03		18.00	96.15	389.15	66.50		262.57		67.95	
342.19	258.14			6.30	125.35	5.18		688.74			
588.04	119.28	570.07		305.57	23.59	856.68		41.01	1.00		
117.20	45.00	2,583.50		38.84		101.86		84.92			
13,352.75	4,707.74	21,316.37	5,033.54	6,563.54	4,905.17	4,547.85	2,347.83	10,567.13	62.25	4,905.62	7.84

Expenditures from United States appropriations received under the

Station.	Amount of appropriation.	Classified expenditures.						
		Salaries.	Labor.	Postage and stationery.	Freight and express.	Heat, light, and water.	Chemical supplies.	Seeds, plants, and sundry supplies.
Alabama	$15,000.00	$10,112.54	$678.78	$26.00	$143.21	....	$773.81	$242.10
Arizona	15,000.00	14,328.84	....	27.61	4.26	....	83.44	49.42
Arkansas	15,000.00	9,309.98	1,308.84	64.15	128.79	$112.43	405.20	308.38
California	15,000.00	11,424.92	1,988.94	3.90	37.11	19.41	199.19	503.52
Colorado	15,000.00	12,812.75	421.30	31.72	1.75	....	533.85	86.48
Connecticut (State)	7,500.00	5,495.89	133.25	123.22	64.80	612.00	301.32	308.71
Connecticut (Storrs)	7,500.00	7,500.00	....	....	....	....	....	....
Delaware	15,000.00	11,188.25	850.76	7.45	93.45	....	1,154.41	252.17
Florida	15,000.00	9,736.67	961.49	58.35	255.26	77.50	878.28	398.68
Georgia	15,000.00	9,858.33	378.45	67.39	161.19	584.38	793.09	192.47
Idaho	15,000.00	10,756.25	1,575.45	16.10	325.93	72.60	614.86	396.84
Illinois	15,000.00	13,208.44	1,035.00	.14	2.78		64.52	55.00
Indiana	15,000.00	11,380.00	692.38	112.00	3.81	....	703.64	32.93
Iowa	15,000.00	8,648.89	3,151.17	165.20	....	276.18	1,201.78	427.28
Kansas	15,000.00	9,108.33	3,236.94	20.00	5.80	2.90	447.99	350.01
Kentucky	15,000.00	14,612.34	....	....	....	....	21.54	1.96
Louisiana	15,000.00	9,574.35	411.60	20.92	44.31	577.38	975.21	287.73
Maine	15,000.00	11,532.55	825.94	73.23	83.85	115.93	119.70	154.91
Maryland	15,000.00	12,712.36	286.50	36.32	2.00	659.82	459.84	196.99
Massachusetts	15,000.00	14,171.24	512.82	....	....	....	....	63.88
Michigan	15,000.00	15,000.00	....	....	....	....	....	....
Minnesota	15,000.00	15,000.00	....	....	....	....	....	....
Mississippi	15,000.00	10,344.82	3,198.82	....	288.48	124.51	328.28	208.75
Missouri	15,000.00	6,431.71	1,663.14	11.61	197.25	120.84	1,213.39	326.20
Montana	15,000.00	12,604.08	175.08	92.65	10.63	16.80	397.75	146.02
Nebraska	15,000.00	11,666.10	618.87	2.89	2.92	....	88.40	374.55
Nevada	15,000.00	9,986.61	1,977.70	68.82	144.34	189.11	167.83	128.37
New Hampshire	15,000.00	11,126.70	1,239.33	7.54	17.95	....	420.96	269.39
New Jersey	15,000.00	11,581.70	727.58	34.64	1.00	273.33	542.21	312.53
New Mexico	15,000.00	8,904.23	2,863.21	44.50	82.70	260.24	498.72	533.04
New York (State)[1]	1,500.00	1,499.76	....	....	....	....	....	....
New York (Cornell)	13,500.00	13,500.00	....	....	....	....	....	....
North Carolina	15,000.00	13,949.17	828.77	81.75	....	105.00	....	....
North Dakota	15,000.00	14,106.58	10.00	....	....	....	177.82	....
Ohio	15,000.00	9,954.10	2,872.95	....	....	....	1,462.82	....
Oklahoma	15,000.00	11,441.58	1,630.71	16.90	....	24.43	242.43	309.67
Oregon	15,000.00	15,000.00	....	....	....	....	....	....
Pennsylvania	15,000.00	10,661.67	903.11	126.64	45.43	42.08	1,124.06	160.91
Rhode Island	15,000.00	9,571.31	3,475.62	9.12	8.34	371.65	98.15	170.91
South Carolina	15,000.00	10,731.76	1,414.82	37.18	76.28	253.51	765.02	216.73
South Dakota	15,000.00	9,041.52	2,989.65	18.72	117.09	....	529.45	363.71
Tennessee	15,000.00	12,794.01	208.20	17.68	64.99	185.41	344.04	35.59
Texas	15,000.00	10,652.60	1,621.54	24.78	112.81	39.42	705.38	365.05
Utah	15,000.00	10,654.34	2,438.82	....	94.59	130.23	554.58	511.07
Vermont	15,000.00	9,334.16	2,586.76	52.29	29.34	182.42	667.87	355.28
Virginia	15,000.00	9,546.66	3,064.48	12.43	63.38	1.25	37.08	96.04
Washington	15,000.00	11,884.57	1,704.12	7.00	....	60.75	464.86	5.17
West Virginia	15,000.00	11,767.16	1,303.72	8.00	....	16.00	210.97	248.01
Wisconsin	15,000.00	8,600.00	3,112.50	3.30	143.55	....	87.64	441.29
Wyoming	15,000.00	12,839.66	75.00	34.82	22.61	42.12	882.72	32.23
Total	720,000.00	547,649.58	61,154.11	1,566.96	2,881.98	5,549.63	21,744.10	9,919.97

[1] Including a balance of $34.78.

act of March 16, 1906 (Adams Act), for the year ended June 30, 1921.

Classified expenditures.										
Fertilizers.	Feeding stuffs.	Library.	Tools, implements, and machinery.	Furniture and fixtures.	Scientific apparatus.	Live stock.	Traveling expenses.	Contingent expenses.	Buildings and repairs.	Balances.
$35.00	$475.95	$137.53	$317.28	$245.86	$1,093.11	$93.75	$620.45	....	$4.63	....
....	....	2.87	24.00	....	78.16	....	165.40	....	236.00	....
217.34	412.62	3.09	599.62	1.25	1,699.83	....	421.68	....	6.80	....
....	....	21.06	6.43	....	54.76	....	250.61	....	490.15	....
....	24.00	11.36	49.85	16.20	299.53	10.50	344.30	....	356.41	....
....	273.53	....	24.05	26.21	....	....	70.22	$11.50	55.30	....
....	....	....	....	....	....	....	....	....	....	....
22.47	....	20.50	36.61	5.50	1,195.00	....	132.72	....	40.71	....
614.60	....	67.67	95.72	135.25	534.58	....	894.64	....	291.31	....
....	1,695.36	64.64	70.77	....	80.20	1,006.33	47.40	....	....	....
....	195.75	6.03	453.23	....	273.13	....	249.23	....	64.60	....
....	210.18	....	204.81	....	112.25	38.50	68.38	....	....	....
18.60	....	70.71	137.21	6.85	800.06	649.69	391.50	....	.62	....
1.00	411.48	....	38.60	....	526.00	....	....	....	152.42	....
....	1,250.04	2.00	228.04	23.64	84.73	96.50	116.31	1.46	25.31	....
....	202.00	....	....	....	....	160.00	2.16	....	....	....
....	167.69	326.72	15.97	446.25	1,687.62	....	454.08	....	10.17	....
....	1,161.35	14.69	3.15	53.00	220.28	114.45	427.61	20.00	79.36	....
....	....	....	48.09	102.72	348.87	....	67.43	....	79.06	....
142.48	8.45	....	....	....	101.13	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....
....	154.25	76.24	....	....	211.55	....	64.30	....	....	....
....	3,786.17	....	153.86	6.60	804.04	24.60	92.62	....	167.97	....
....	....	29.60	9.50	60.74	692.84	....	764.31	....	....	....
....	208.70	....	370.81	....	662.24	844.18	160.34	....	....	....
....	340.48	53.79	73.28	2.50	2.00	1,588.85	276.32	....	....	....
....	553.86	....	78.89	28.50	825.17	....	80.27	....	351.44	....
8.87	360.00	88.40	475.71	140.11	38.80	....	8.94	....	406.18	....
33.54	473.11	3.33	334.41	41.92	294.98	350.00	....	....	282.07	....
....	....	....	....	....	....	....	....	....	....	$0.24
....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	35.31	....	....	....	....
....	....	....	....	....	89.79	615.71	....	....	....	....
....	....	17.17	32.75	....	383.31	....	....	10.00	266.90	....
....	551.66	27.00	197.18	33.00	166.31	115.63	119.40	....	124.10	....
....	....	....	....	....	....	....	....	....	....	....
2.00	70.53	191.83	14.39	9.15	1,275.64	....	155.80	.46	216.30	....
....	787.32	9.00	109.20	....	176.39	80.00	....	....	132.99	....
....	410.94	7.50	400.92	132.26	436.20	100.00	5.89	....	10.99	....
124.03	248.45	16.00	212.65	227.39	689.37	....	....	63.33	358.64	....
....	....	67.73	512.03	128.10	226.27	....	303.71	....	112.24	....
....	132.45	....	30.91	....	1,131.50	57.64	....	....	125.92	....
....	....	8.00	31.50	....	340.37	....	223.85	....	12.65	....
3.78	249.59	7.46	8.75	17.75	488.94	425.00	183.51	....	407.10	....
206.75	1,405.26	2.75	3.25	....	367.92	....	45.16	....	147.59	....
3.75	....	10.00	30.66	....	465.17	....	363.95	....	....	....
29.75	452.58	5.50	69.80	68.65	562.68	....	257.18	....	....	....
....	1,845.84	....	91.21	76.69	285.98	312.00	....	....	....	....
....	692.96	....	114.44	....	94.50	68.90	69.14	....	30.90	....
1,463.96	19,212.55	1,370.17	5,709.53	2,036.09	19,901.20	6,787.54	7,898.81	106.75	5,046.83	.24

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906.

State or Territory.	Hatch Act.		Adams Act.	
	1888–1920	1921	1906–1920	1921
Alabama	$493,956.42	$15,000.00	$191,619.89	$15,000.00
Arizona	459,803.10	15,000.00	194,955.61	15,000.00
Arkansas	493,139.12	15,000.00	194,900.00	15,000.00
California	495,000.00	15,000.00	194,926.84	15,000.00
Colorado	494,718.82	15,000.00	193,638.93	15,000.00
Connecticut	495,000.00	15,000.00	195,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	493,382.87	15,000.00	190,475.12	15,000.00
Florida	494,966.06	15,000.00	194,995.06	15,000.00
Georgia	490,593.43	15,000.00	182,092.87	15,000.00
Idaho	419,324.13	15,000.00	190,842.22	15,000.00
Illinois	494,564.95	15,000.00	194,851.62	15,000.00
Indiana	494,901.19	15,000.00	195,000.00	15,000.00
Iowa	495,000.00	15,000.00	195,000.00	15,000.00
Kansas	494,995.00	15,000.00	195,000.00	15,000.00
Kentucky	494,996.57	15,000.00	195,000.00	15,000.00
Louisiana	495,000.00	15,000.00	195,000.00	15,000.00
Maine	494,999.62	15,000.00	195,000.00	15,000.00
Maryland	494,967.40	15,000.00	194,236.48	15,000.00
Massachusetts	494,617.70	15,000.00	195,000.00	15,000.00
Michigan	494,676.10	15,000.00	191,341.20	15,000.00
Minnesota	494,917.78	15,000.00	194,345.00	15,000.00
Mississippi	495,000.00	15,000.00	195,000.00	15,000.00
Missouri	490,097.24	15,000.00	194,999.90	15,000.00
Montana	405,000.00	15,000.00	192,417.04	15,000.00
Nebraska	494,932.16	15,000.00	195,000.00	15,000.00
Nevada	494,214.32	15,000.00	193,180.28	15,000.00
New Hampshire	495,000.00	15,000.00	195,000.00	15,000.00
New Jersey	494,949.97	15,000.00	194,558.78	14,833.2
New Mexico	459,509.05	15,000.00	195,000.00	15,000.0
New York	494,765.94	14,999.49	194,498.03	14,965.2
North Carolina	495,000.00	15,000.00	180,000.00	15,000.0
North Dakota	436,502.26	15,000.00	194,638.85	15,000.0
Ohio	495,000.00	15,000.00	193,514.02	15,000.0
Oklahoma	419,568.96	15,000.00	176,360.56	15,000.0
Oregon	480,156.64	15,000.00	190,000.00	15,000.0
Pennsylvania	494,967.43	15,000.00	194,995.41	15,000.0
Rhode Island	495,000.00	15,000.00	192,464.20	15,000.0
South Carolina	494,542.15	15,000.00	193,460.12	15,000.
South Dakota	438,250.00	15,000.00	190,000.00	15,000.
Tennessee	495,000.00	15,000.00	195,000.00	15,000.
Texas	495,000.00	15,000.00	192,592.26	15,000.
Utah	360,000.00	15,000.00	194,821.94	15,000.
Vermont	495,000.00	15,000.00	195,000.00	15,000.
Virginia	492,824.12	15,000.00	194,949.01	15,000.
Washington	432,102.65	15,000.00	191,080.11	15,000.
West Virginia	494,968.71	15,000.00	192,859.12	15,000.
Wisconsin	495,000.00	15,000.00	195,000.00	15,000.
Wyoming	480,000.00	15,000.00	195,000.00	15,000.
Total	23,142,121.86	719,999.49	9,264,611.47	719,798.

LIST OF PUBLICATIONS OF THE EXPERIMENT STATIONS DURIN[G] THE FISCAL YEAR 1921.

AGRICULTURAL CHEMISTRY—AGROTECHNY.

Concerning Inosite Phosphoric Acids:—I. Synthesis of Phytic Acid.—II. Co[m]position of Inosite Phosphoric Acid of Plants. By R. J. Anderson. (Ne[w] York State Sta. Tech. Bul. 29, pp. 22.)

Unfermented Fruit Juices. By W. V. Cruess. (California Sta. Circ. 220, p[p.] 32, figs. 18.)

Apple Candy.—A Commercial Use for Cull Apples. By T. H. Abell. (Utah St[a.] Bul. 179, pp. 14, figs. 7.)

Sugar Beet and Apple Sirups. By L. E. Longley. (Idaho Sta. Circ. 14, pp. [ ] figs. 4.)

Products and Utilization of Muscadine Grapes. By W. J. Young. (Sou[th] Carolina Sta. Bul. 206, pp. 37, figs. 5.)

Commercial Production of Grape Sirup. By W. V. Cruess. (California Sta. Bul. 321, pp. 401–416, figs. 5.)
The Evaporation of Grapes. By W. V. Cruess, A. W. Christie, and F. C. H. Flossfeder. (California Sta. Bul. 322, pp. 421–471, figs. 11.)
The Clarification of Cane Juice Without Chemical Treatment. By F. W. Zerban. (Louisiana Stas. Bul. 173, pp. 26, figs. 2.)
The Prevention of Sugar Deterioration. By N. Kopeloff, C. J. Welcome, and L. Kopeloff. (Louisiana Stas. Bul. 175, pp. 58, fig. 1.)
Factors Determining the Keeping Quality of Cane Sugar. By N. and L. Kopeloff. (Louisiana Stas. Bul. 170, pp. 63, fig. 1.)
Paint Bulletin, Food Department. (North Dakota Sta. Paint Bul. 1 (1919), No. 7, pp. 113–138, fig. 1.)

BOTANY.

The Malvaceous Plants of Texas. By H. C. Hanson. (Texas Sta. Circ. 22, pp. 18.)
Normal and Abnormal Germination of Grass Fruits. By J. Zinn. (Maine Sta. Bul. 294, pp. 197–216, pls. 4.)
Sturtevant's Notes on Edible Plants. By U. P Hedrick. (New York State Sta. Rpt. 2 (1919), part II, pp. VII+686, pl. 1.)

GENETICS.

Asexual Inheritance in the Violet (*Viola odorata*). By R. D. Anthony. (New York Sta. Tech. Bul. 76, pp. 55, figs. 12.)
Inbreeding Animals.—I, Experimental Evidence; II, Experimental Results. By F. A. Hays. (Delaware Sta. Bul. 123, pp. 49, figs. 9.)
The Occurrence of Red Calves in Black Breeds of Cattle. By L. J. Cole and S. V. H. Jones. (Wisconsin Sta. Bul. 313, pp. 35, figs. 4.)
A Comparison of Some Traits of Conformation of Southdown and Rambouillet Sheep and of their F_1 Hybrids, with Preliminary Data and Remarks on Variability in F_2. By E. G. Ritzman and C. B. Davenport. (New Hampshire Sta. Tech. Bul. 15, pp. 32, figs. 25.)
Broodiness in Domestic Fowl.—Data Concerning Its Inheritance in the Rhode Island Red Breed. By H. D. Goodale, R. Sanborn, and D. White. (Massachusetts Sta. Bul. 199, pp. 93–116, figs. 4.)
Studies on the Inheritance of Egg Weight.—I, Normal Distribution of Egg Weight. By P. Hadley and D. W. Caldwell. (Rhode Island Sta. Bul. 181, pp. 64, pl. 1, figs. 42.)

METEOROLOGY.

Meteorological Observations at the Massachusetts Agricultural Experiment Station. By J. E. Ostrander and G. E. Lindskog. (Massachusetts Sta. Met. Buls. 378–380, pp. 4 each.)
Meteorological Observations at the Massachusetts Agricultural Experiment Station. By J. E. Ostrander and H. W. Poole. (Massachusetts Sta. Met. Buls. 381–389, pp. 4 each.)
Ohio Weather for 1919. By W. H. Alexander and C. A. Patton. (Ohio Sta. Bul. 345, pp. 481–570, figs. 62.)

SOILS.

Testing Soils for Acidity. By E. Truog. (Wisconsin Sta. Bul. 312, pp. 24, pl. 1, figs. 11.)
Lime Requirement of Pennsylvania Soils. By J. W. White. (Pennsylvania Sta. Bul. 164, pp. 36, figs. 7.)
The Present Status of Alkali. By W. P. Kelley. (California Sta. Circ. 219.)
I. Report on Soil Experiment Fields.—II. Maintenance of Fertility. By G. Roberts and A. E. Ewan. (Kentucky Sta. Bul. 228, pp. 89–131, fig. 1.)
The Illinois System of Permanent Soil Fertility as Developed by Cyril G. Hopkins. By R. Stewart. (Illinois Sta. Circ. 245, pp. 20, figs. 5.)
Soil Fertility. By M. M. McCool, C. E. Miller, and G. M. Grantham. (Michigan Sta. Pop. Bul. 290, pp. 39, figs. 15.)
Soil Fertility Experiments on DeKalb, Volusia, and Westmoreland Soils. By J. W. White and F. J. Holben. (Pennsylvania Sta. Bul. 166, pp. 23, figs. 5.)

Some Observations on Soil Fertility and Crop Production. By W. H. Jordan, G. W. Churchill, and J. D. Luckett. (New York State Sta. Bul. 473, pop. ed., pp. 18, fig. 1.)

Keeping Soils Productive. By R. R. Hudelson. (Missouri Sta. Circ. 102, pp. 24, figs. 8.)

The Relation of the Phosphoric Acid of the Soil to Pot Experiments. By G. S. Fraps. (Texas Sta. Bul. 267, pp. 53, figs. 2.)

The Carbon Dioxid of the Soil Air. By H. W. Turpin. (New York Cornell Sta. Mem. 32, pp. 319–362, 17.)

Some Effects of Potassium Salts on Soils. By R. S. Smith. (New York Cornell Sta. Mem. 35, pp. 565–605, figs. 3.)

Nitrate Production in Field Soils in Illinois. By A. L. Whiting and W. R. Schoonover. (Illinois Sta. Abs, of Bul. 225, pp. 4.)

Nitrification in Acid Soils. By R. E. Stephenson. (Iowa Sta. Res. Bul. 58, pp. 331–349.)

Nitrification in Texas Soils. By G. S. Fraps. (Texas Sta. Bul. 259, pp. 37, figs. 2.)

Nitrogen from the Air. By J. G. Hutton. (South Dakota Sta. Soil Survey Circ. 1, 1920, pp. 4.)

The Fixation of Nitrogen in Colorado Soils.—A Study of the Wellington District, Laramer County, Colorado. By W. P. Headden. (Colorado Sta. Bul. 258, pp. 48, fig. 1.)

The Management of Sandy Soils under Irrigation. By H. K. Dean. (Oregon Sta. Bul. 177, pp. 26, figs. 13.)

Summer Fallowing Experiments in the Judith Basin. By W. P. Baird. (Montana Sta. Bul. 138, pp. 39, figs. 3.)

Soils of the Detroit Area. By M. M. McCool and G. M. Grantham. (Michigan Sta. Spec. Bul. 104, pp. 31, figs. 15, pl. 1.)

Report of Golden Valley Peat Experimental Fields, 1918–19. By F. J. Alway. (Minnesota Sta. Bul. 194, pp. 116, figs. 43.)

Biennial Report Oregon Soil Investigations, 1918–1920. (Oregon Sta. Rpt. 1918–1920, pp. 46, figs. 34.)

The Soils of Northern Wisconsin. By A. R. Whitson, T. J. Dunnewald, and C. Thompson. (Wisconsin Sta. Bul. 306, pp. 45, pls. 5, figs. 3.)

Soil Survey Reports of Iowa. By W. H. Stevenson and P. E. Brown. Iowa Sta. Soil Survey Rpts.—
- No. 4, Webster County Soils. pp. 48, figs. 11, maps 2.
- No. 5, Lee County Soils. pp. 48, figs. 11, map 1.
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The Chemical Composition of the Soils of the Camden Area in New Jersey. By A. W. Blair and H. C. McLean. (New Jersey Stas. Bul. 346, pp. 40, figs. 2.)

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Bat Guano and its Fertilizing Value. By W. A. Albrecht. (Missouri Sta. Bul. 180, pp. 15, figs. 7.)
Some Observations Upon the Effect of Borax in Fertilizers. By W. J. Morse. (Maine Sta. Bul. 288, pp. 89–120, pls. 2, figs. 10.)
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Some of the Effects of the War Upon Fertilizers. By L. L. Van Slyke. (New York State Sta. Bul. 471, pp. 10.)
Bulletin of Immediate Information [Calling the Attention of Purchasers of Fertilizers to Certain Facts]. (Connecticut State Sta. Bul. of Immediate Inform. No. 14, p. 1.)

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Cotton Variety Experiments, Substation No. 3, Angleton, Texas. By E. B. Reynolds. (Texas Sta. Bul. 274, pp. 10.)
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Cultural Experiments with Cotton (Delta Branch Station). By G. B. Walker and W. E. Ayres. (Mississippi Sta. Circ. 35, pp. 4.)
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Field Experiments Which Included the Soy Bean. By B. L. Hartwell. Rhode Island Sta. Bul. 183, pp. 15.)

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Sweet Potato Culture in Missouri. By J. T. Rosa, Jr. (Missouri Sta. Circ. 103, pp. 12, figs. 6.)
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Bacteriological Studies of Methods of Preparing a Seedbed for Wheat. By P. L. Gainey. (Kansas Sta. Tech. Bul. 8, pp. 64, figs. 10.)
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Sixteen Years of Dry Farm Experiments in Utah. By F. S. Harris, A. F. Bracken, and I. J. Jensen. (Utah Sta. Bul. 175, pp. 43, figs. 4.)

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Should the Orchard be Fertilized? By R. C. Collison and J. D. Luckett. (New York State Sta. Bul. 477, pop. ed., pp. 11, fig. 1.)
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Orchard Rejuvenation in Southern Ohio (Second Report). By F. H. Ballou and I. P. Lewis. (Ohio Sta. Bul. 339, pp. 42, figs. 20.)
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Western North Carolina Apple Show. (North Carolina Sta. Farmer Market Bul. 7 (1920), No. 38, pp. 12.)
Condition of the Commercial Apple Crop of the United States June 1. (Missouri Fruit Sta. [Leaflet] No. 1, pp. 4.)
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Final Estimate of the 1920 Apple Crop. By J. R. Duncan. (Missouri Fruit Sta. Fruit News Notes 5, pp. 8.)

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The Grape. By J. C. C. Price. (Alabama Sta. Bul. 211, pp. 35–50, figs. 15.)
Commercial Grape Growing. By J. R. Cooper. (Arkansas Sta. Bul. 17[illegible], pp. 39, figs. 24.)
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Muscadine Grapes: Culture and Varieties. By W. J. Young. (South Carolina Sta. Bul. 205, pp. 48, figs. 19.)

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Forest and Shade Trees for Planting in Idaho, Including a Price List for 1921. By F. G. Miller. (Idaho Sta. Cir. 16, pp. 4.)
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Potato Diseases in Minnesota. By G. R. Bisby and A. G. Tolaas. (Minnesota Sta. Bul. 190, pp. 44, figs. 29.)

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Potato Mosaic. By D. Folsom. (Maine Sta. Bul. 292, pp. 157–184, pls. 2.)

Potato Leafroll. By D. Folsom. (Maine Sta. Bul. 297, pp. 35–52, pls. 4, figs. 3.)

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Diseases of the Sweet Potato in Mississippi and Their Control. By D. C. Neal. (Mississippi Sta. Bul. 190, pp. 16, figs. 14.)

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Fruit diseases.

Diseases of Illinois Fruits. By H. W. Anderson. (Illinois Sta. Circ. 241, pp. 155, pls. 2, figs. 58.)

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Brown Rot of Apricots. By W. L. Howard and W. T. Horne. (California Sta. Bul. 326, pp. 71–88, figs. 6.)

Dendrophoma Leaf Blight of Strawberry. By H. W. Anderson. (Illinois Sta. Bul. 229, pp. 127–136, figs. 3.)

Vegetable diseases.

Bacterial Blight of Beans. By C. W. Rapp. (Oklahoma Sta. Bul. 131, pp. 39, figs. 15.)

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Eggplant Blight. By C. W. Edgerton and C. C. Moreland. (Louisiana Stas. Bul. 178, pp. 44, figs. 18.)

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Tomato Wilt. By J. A. McClintock. (Georgia Sta. Bul. 138, pp. 37–49, figs. 5.)
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Fruit insects.

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The Reaction of Milk in Relation to the Presence of Blood Cells and of Specific Bacterial Infections of the Udder. By J. C. Baker and R. S. Breed. (New York State Sta. Tech. Bul. 80, pp. 19.)

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The Value of Commercial Vaccines and Bacterins Against Fowl Cholera. By L. Van Es and H. M. Martin. (Nebraska Sta. Res. Bul. 18, pp. 11.)
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Chemical and Pharmacological Examination of the Woody Aster. By O. A. Beath. (Wyoming Sta. Bul. 123, pp. 41–66, figs. 9.)
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The Horse and the Tractor.—An Economic Study of Their Use on Farms in Central Illinois. By W. F. Handschin, J. B. Andrews, and E. Rauchenstein. (Illinois Sta. Bul. 231, pp. 171–224, figs. 22.)

Farm Records and Accounts. By H. M. Eliot and H. B. Killough. (Texas Sta. Bul. 264, pp. 40, figs. 8.)
Some Types of Irrigation Farming in Utah. By E. B. Brossard. (Utah Sta. Bul. 177, pp. 140, figs. 21.)
The Agriculture of Utah. By F. S. Harris. (Utah Sta. Circ. 44, pp. 32, figs. 19.)

REPORTS, REGULATORY, AND MISCELLANEOUS PUBLICATIONS.

Reports.

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California Station, Annual Report, 1919–20. pp. 159, pl. 1.
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Connecticut State Station, Forty-third Annual Report, 1919. pp. XVI+506, pls. 56, figs. 28.
Connecticut Storrs Station, Biennial Report, 1917–18, 1918–19. pp. IX+190, figs. 30.
Delaware Station, Annual Report of the Director. Bul. 125, pp. 30.
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Work and Progress of the Agricultural Experiment Station for the Year Ended December 31, 1920. (Idaho Station Bul. 122. pp. 64, figs. 3.)
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Indiana Station, Thirty-third Annual Report, 1920. pp. 59, figs. 5.
Iowa Station, Annual Report, 1919. By C. F. Curtiss. pp. 53.
Kansas Station, Director's Report, 1918–19. pp. 88.
Kentucky Station, Thirty-second Annual Report, 1919, I. pp. 63, figs. 4.
Louisiana Stations, Thirty-first Annual Report, 1919. By W. R. Dodson. pp. 38.
Louisiana Stations, Thirty-second Annual Report, 1920. By W. H. Dalrymple. pp. 32.
Maryland Station, Thirty-third Annual Report, 1920. By H. J. Patterson. pp. IX+140, figs. 61.
Massachusetts Station, Annual Report, 1919. Pub. Doc. 31, pp. 47A+268, pls. 15, figs. 35.
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Minnesota Station, Twenty-eighth Annual Report, 1919–20. pp. 91.
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Montana Station, Twenty-sixth Annual Report, 1919. By F. B. Linfield. pp. 48, fig. 1.
Nebraska Station, Thirty-fourth Annual Report, 1920. pp. 54.
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New York State Station, Thirty-seventh Annual Report, 1918. pp. VII+484, pls. 37, figs. 46.
New York State Station, Director's Report for 1919. By W. H. Jordan. Bul. 470, pp. 28.
New York State Station, Thirty-second Annual Report of the College of Agriculture and of the Agricultural Experiment Station, 1919. Vol. 1, pp. CIV+1106+[8], pls. 17, figs. 175.
New York State Station, Thirty-third Annual Report, 1920. pp. 79+[4].
New York State Station, Director's Report for 1920. Bul. 483, pp. 23.
North Carolina Station, Forty-third Annual Report, 1920. pp. 69.
North Dakota Station, Report of the Director, 1919–20. By P. F. Trowbridge. Bul. 146, pp. 48, figs. 6.

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Ohio Station, Thirty-ninth Annual Report, 1919–20. Bul. 346, pp. XXXX+[6].
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Washington Station, Twenty-ninth Annual Report, 1919, Bul. 155. pp. 57.
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Wyoming Station, Thirtieth Annual Report. 1919–1921. pp. 143.
Annual Report of the Director of the Experiment Station on Work Done Under the Local Experiment Law in 1920. By J. F. Duggar. (Alabama Sta. Circ. 44, pp. 28.)
Report of Northeast Demonstration Farm and Experiment Station, 1918–1919. By M. J. Thompson. (Minnesota Station Rpt. 1919, pp. 28, figs. 4.)
Report of Northwest Experiment Station, Crookston, 1919. By C. G. Selvig. (Minnesota Sta. Bul., Crookston Ser. 13 (1920), No. 2, pp. 32.)
General Report, North Central Experiment Station, 1915–1919. By O. I. Bergh. (Minnesota Sta. Rpt. 1919, pp. 80, figs. 30.)
Report of West Central Experiment Station, Morris, 1919. By P. E. Miller. (Minnesota Sta. Rpt. 1919, pp. 47.)
Report from Holly Springs Branch Experiment Station for 1915–1920, inclusive. By C. T. Ames. (Mississippi Sta. Bul. 193, pp. 22, figs. 2.)
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Report from South Mississippi Branch Experiment Station for 1918–1920, inclusive. By E. B. Ferris. (Mississippi Sta. Bul. 194, pp. 23.)
Thirteenth and Fourteenth Annual Reports of the State Demonstration Farms, 1918–19. By W. R. Porter. (North Dakota Sta. Bul. 135, pp. 83.)
Fifteenth Annual Report of the State Demonstration Farms, 1920. By E. I. Olsen. (North Dakota Sta. Bul. 148, pp. 38, figs. 8.)
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Edgeley Substation Report, 1914 to 1920. (North Dakota Sta. Bul. 145, pp. 44.)
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Monthly Bulletin of the Western Washington Experiment Station, Puyallup, Wash.—
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Fertilizer Report for 1920. By E. H. Jenkins and E. M. Bailey. (Connecticut State Sta. Bul. 223, pp. 66.)

Commercial Fertilizers. By E. G. Proulx et al. (Indiana Sta. Bul 241, pp. 99, fig. 1.)

The Fertilizer Control Law and How to Comply With It. By E. G. Proulx. (Indiana Sta. Circ. 96, pp. 6, fig. 1.)

Fertilizer Control in 1918. By C. O. Swanson, W. L. Latshaw, and L. T. Anderegg. (Kansas Sta. Insp. Circ. 10, pp. 9.)

Commercial Fertilizers. By H. E. Curtis, W. Rodes, and H. R. Allen. (Kentucky Sta. Bul 224, pp. 259–372.)

Commercial Fertilizers, 1920. By C. D. Woods. (Maine Sta. Off. Insp. 97, pp. 65–88.)

Inspection of Commercial Fertilizers for 1920. By H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (New Hampshire Sta. Bul. 196, pp. 15.)

Analyses of Commercial Fertilizers, Fertilizer Supplies, and Home Mixtures, 1920. By C. S. Cathcart. (New Jersey Stas. Bul. 344, pp. 47.)

Analyses of Commercial Fertilizers and Ground Bone. Analyses of Agricultural Lime. By C. S. Cathcart. (New Jersey Stas. Bul. 349, pp. 45.)

Fertilizer Registrations for 1921. By C. S. Cathcart. (New Jersey Stas. Bul. 350, pp. 35.)

Report of Analyses of Samples of Commercial Fertilizers Collected by the Commissioner of Agriculture During 1919. (New York State Sta. Bul. 467, pp. 61–112.)

Inspection of Commercial Fertilizers, 1920. (New York State Sta. Bul. 480, pp. 59.)

Inspection of Commercial Fertilizers. By P. H. Wessels. (Rhode Island Sta. Ann. Fert. Circ., pp. 11.)

Analyses of Commercial Fertilizers. By R. N. Brackett and H. M. Stackhouse. (South Carolina Sta. Bul. 203, pp. 72.)

Commercial Fertilizers in 1919–20. By G. S. Fraps and S. E. Asbury. (Texas Sta. Bul. 265, pp. 25.)

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Report on Commercial Feeding Stuffs, 1919. By E. M. Bailey. (Connecticut State Sta. Bul. 221, pp. 345–393.)

Report on Commercial Feeding Stuffs, 1920. By E. M. Bailey. (Connecticut State Sta. Bul. 229, pp. 293–323.)

Commercial Feeding Stuffs.—Quarterly Report, October 1, 1919–December 31, 1919. By E. G. Proulx et al. (Indiana Sta. Bul. 242, pp. 83, fig. 1.)

Commercial Feeding Stuffs.—Quarterly Report, January 1, 1920–March 31, 1920. By E. G. Proulx et al. (Indiana Sta. Bul. 243, pp. 64.)

Commercial Feeding Stuffs. By E. G. Proulx et al. (Indiana Sta. Bul. 252, pp. 15.)

Commercial Feeding Stuffs, 1919–20. By C. D. Woods. (Maine Sta. Off. Insp. 96, pp. 29–64.)

Inspection of Commercial Feedstuffs. By P. H. Smith and E. M. Bradley. (Massachusetts Sta. Bul. 13, Control Series, pp. 27.)

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Inspection of Commercial Feeding Stuffs. By H. R. Kraybill and T. O. Smith. (New Hampshire Sta. Bul. 195, pp. 46.)

Analyses of Commercial Feeding Stuffs and Registrations for 1920. By C. S. Cathcart. (New Jersey Stas. Bul. 342, pp. 62.)

Inspection of Feeding Stuffs. (New York State Sta. Bul. 469, pp. 319.)

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Inspection of Commercial Feeds. By P. H. Wessels. (Rhode Island Sta. Ann. Feed Circ., 1920, pp. 11.)

Commercial Feeding Stuffs. By F. D. Fuller, S. D. Pearce, and G. S. Fraps. (Texas Sta. Bul. 268, pp. 333, figs. 2.)

The Texas Feed Law.—Revised Rules and Regulations. By F. D. Fuller. (Texas Sta. Control Circ. E, pp. 8.)

The Texas Feed Law Requirements and Administration. By F. D. Fuller. (Texas Sta. Control Circ. F, pp. 20, figs. 2.)

Regulatory Bulletins—Foods and Drugs.

Food Products and Drugs, 1919, I. By E. M. Bailey. (Connecticut State Sta. Bul. 219, pp. 213–259.)

Food Products and Drugs, 1911, II.—Diabetic Foods. By E. M. Bailey. (Connecticut State Sta. Bul. 220, pp. 265–342.)

Twenty-fifth Report on Food Products and Thirteenth Report on Drug Products. By E. M. Bailey. (Connecticut State Sta. Bul. 227, pp. 217–283.)

Drugs and Foods. By C. D. Woods. (Maine Sta. Off. Insp. 95, pp. 28.)

Special Bulletin, Food Department. (North Dakota Sta. Spec. Bul. 6 (1920), No. 2, pp. 13–28.)

Regulatory Bulletins—Seeds.

Commercial Agricultural Seeds. By C. D. Woods. (Maine Sta. Off. Insp. 98, pp. 89–112.)

Third Annual Report. By W. W. Robbins and G. E. Egginton. (Colorado Sta. Seed Lab. Bul. 2 (1919), No. 2, pp. 27, figs. 5.)

Seed Inspection for 1919. By F. L. Holmes. (Maryland Sta. Bul. 238, pp. 23–55.)

Results of Seed Tests for 1920. By M. G. Eastman. (New Hampshire Sta. Bul. 197, pp. 16.)

The New York Seed Law and Seed Testing. By M. T. Munn. (New York State Sta. Bul. 476, pp. 28, figs. 4.)

Regulatory Bulletins—Miscellaneous.

Sixth Annual Report of the Montana Grain Inspection Laboratory. By A. Atkinson and E. W. Jahnke. (Montana Sta. Bul. 135, pp. 21, figs. 8.)

Seventh Annual Report of the Montana Grain Inspection Laboratory. By P. V. Cardon, W. O. Whitcomb, and W. F. Day. (Montana Sta. Bul. 136, pp. 32, figs. 4.)

Sixth Annual Report of the Creamery License Division. 1920. By O. E. Reed and T. H. Broughton. (Indiana Sta. Circ. 97, pp. 16, figs. 2.)

Stallion Enrollment, IX. By R. B. Cooley. (Indiana Sta. Circ. 99, pp. 80.)

Kansas State Live Stock Registry Board [Report No. 9, 1919]. By F. W. Bell. (Kansas Sta. Insp. Circ. 11, pp. 127.)

Federal and State Laws Regulating the Propagation and Distribution of Nursery Stock. By L. Haseman. (Missouri Sta. Circ. 99, pp. 24.)

Analyses of Materials Sold as Insecticides and Fungicides During 1920. By C. S. Cathcart and R. L. Willis. (New Jersey Stas. Bul. 343, pp. 20.)

Inspection of Insecticides and Fungicides, 1920. (New York State Sta. Bul. 481, pp. 18.)

Plant Inspection in Missouri. By K. C. Sullivan. (Missouri Sta. Circ. 101, pp. 16, figs. 5.)

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Publication Lists and Miscellaneous.

Publications Available for Free Distribution. (Idaho Sta. Circ. 13, pp. 2.)

Available Publications. (Maine Sta. [Leaflet], pp. 2.)

List of Available Publications. By C. D. Woods. (Maine Sta. [Leaflet], 1919, pp. 2.)

List of Publications. (Rhode Island Sta. [Pamphlet], pp. VIII.)

General Index to Colorado Station Publications. Compiled by A. Dilts. (Colorado Sta. Bul. 263, pp. 69.)

Filing Agricultural Bulletins and Circulars. By H. Durham. (Kansas Sta. Circ. 85, pp. 13, figs. 3.)

Reliable Agricultural Information and How to Secure It. By A. B. Conner. (Texas Sta. Circ. 23, pp. 16, figs. 8.)

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UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF EXPERIMENT STATIONS

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WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1922

By E. W. Allen, W. H. Beal, and E. R. Flint

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CONDITIONS OF THE YEAR

The fiscal year 1922 was a more favorable one for the agricultural experiment stations in the United States than any since the World War. Material relief from straitened financial conditions was provided, and the support of the system as a whole was the largest ever accorded it. In two-thirds of the States direct appropriations by the legislatures or allotments through the agricultural colleges increased the support for research, the total amount of this increase over the preceding year being nearly $1,300,000.

In individual cases this increase ranged from less than $1,000 to as much as $230,000 (in California), the latter, however, being due in part to change in the basis of estimating the amount used by the station out of general funds of the college. In over half the cases the amount of the additional funds ranged from $10,000 to $20,000. The wide distribution of these, covering so large a proportion of the stations, was quite as significant as the total amount, in the measure of relief afforded.

Another factor in the improved situation was a more liberal attitude on the part of the colleges, made possible by the relief which these had secured from the financial pressure they had themselves been under following the close of the war. The unfavorable position of the stations was beginning to make itself felt in the colleges and impressed upon the authorities the necessity for relief. Along with this was an increasing realization of the extent to which the ability of the colleges to keep their instruction fresh and to meet the changing demands of agriculture is directly dependent upon research.

The truth of this was brought home to a surprising degree by the few years of suspended growth during and following the war. Nowhere was it more felt than in the extension service, which had been rapidly built up and for which it was thought the accumulated fund of information would suffice for a considerable time. The application of existing facts and the stimulation of wider thinking and discussion set in motion by the extension work soon demonstrated the fallacy of this, for it very materially increased the call for assistance and presented new problems for study. It demanded, morever, a different kind of information, more far-reaching and enlightening, less empirical in many cases, in order that it might be better understood and more intelligently applied. The extension workers therefore became the most forceful advocates for continued investigation of a fundamental type and on a competent scale.

PROGRESS OF AGRICULTURAL RESEARCH

Farming is one kind of work which can not be carried on by fixed rule. It calls for adaptation of rules to conditions that are rarely twice the same in different years or localities. This has often made the laying down of specific advice a difficult matter for the man of science, and has sometimes led to his being regarded as vague or unpractical because of his caution in making broad practical generalizations. The recognition of this difficulty is one of the products of the extension method of imparting infomation. The carrying out of the latter soon leads to the necessity for deeper diagnosis and more intelligent prescription than the superficial facts enable.

The attempt to get at the whole truth, to disclose the real natur of a problem or difficulty, to combine reason with precept in prescribing for it, so as to furnish that understanding which lies back of the keen judgment and "common sense" of the practical man, requires much more intimate and fundamental type of investigation than tha which seeks merely superficial results or empirical rules. It calls fo research of as abstract and exacting a type as that employed in an branch of science; and it requires those personal qualities of imagination and ingenuity which do not always accompany a wide scientifi knowledge. It calls for patience with the methods of research, as th general public now increasingly realizes.

The reason lying back of a fact may be quite as important as th fact itself. The isolated fact may be well-nigh sterile or even dan gerous unless it is understood, for if its limitations and its relationship are not known it may be misapplied or used with too much confidenc

Hence more and more the necessity is seen for getting away fro the conventional methods which attempt to give direct answers complex practical questions in the form in which they are commonl seen. The effort to go deeper imparts originality to the conceptio of the problem and the means of approaching it. Without analys of many-sided questions and the devising of means for studying the essential parts step by step, the final result is likely to be inconclusiv and unsatisfying, if not unreliable. The understanding of what really involved in the intricate questions as met with in practice li at the basis of successful investigation. When the essential featur of such questions are dissociated and studied for themselves, speci

investigations may be devised which give definite and often absolute results from which to develop both theory and practice. Until this is done results are largely comparative and relative, and subject to change with each variation in local or economic conditions.

Experiments find their justification not merely in themselves, but in the ends they serve. When they cease to meet the situation either by giving new evidence or suggestions or by supplying results sufficiently informing for the purpose, they need to be changed. The continued accumulation of data without being sure that they are meeting specific needs is inexpert and wasteful. The whole spirit of investigation is progress, which will develop one fact or point after another, or will open up the problem in a new light so that it can be attacked more effectively.

The type of station activity is therefore rapidly changing, a fact which the public sometimes views with concern lest the subject itself rather than its agricultural bearing may be the objective. Naturally this is to be guarded against, but it seldom occurs and is checked by the type of administration which keeps the mission and motive of the station clearly in the foreground.

It is inevitable that to be constructive and progressive, investigation should be much more technical than formerly; and the immediate results may appear of little importance to agriculture. This is the case, for example, with some of the fundamental studies in the relation between the plant and its environment, the soil in its relation to the life within it and the growth upon it, but it is through such studies that more intelligent practice based on an understanding of the facts must be founded.

The effect of this more intensive type of investigation is reflected in the requirements of the present day. What sufficed in the way of personnel, facilities, and equipment 10 years ago will no longer meet the situation. Success calls for investigators of extensive and severe training to give them vision and skill, and with demonstrated ability in the creative field of research. This fact is now recognized very generally as being in the interest of actual economy in the study of practical questions rooted in fundamental science; and the higher standards are being put into effect as far as financial and other considerations will permit.

Lack of funds has limited many of the stations in developing their work in accordance with these requirements, and salary precedent or adherence to a rigid scale in the college also acts as a bar. Means for attracting and holding competent investigators remains one of the great problems of the experiment stations. Steady progress in that direction, however, is evidenced by the increasing number of workers with advanced degrees, the type of work which they are doing, and less frequent change from one institution to another.

DIVERSITY OF WORK

Another factor which frequently enters into the situation is the fact that stations have "too many irons in the fire" for the resources at their disposal. In responding to the demands upon them they are attempting to cover too broad a field. This is not true of all, as some have continued to concentrate rather closely and not to enter upon

new undertakings until added funds were available; but quite often more lines are being attempted than can be carried on with vigor.

Instead of being regarded as a criticism of the stations this is to be taken as illustrating the ambition of their workers, and an earnest of the desire to serve. Every year sees a considerable increase in the number of projects. This number now aggregates something over 5,000, an average of about 100 to the station. This is manifestly too large a number for the average station to carry to advantage with its resources. As a result a considerable number are temporarily inactive or only prosecuted in an incidental way. They are usually the response to a request that the station do something on the subject.

Despite the large number of separate undertakings, the maximum attention is usually restricted to a relatively few projects. This concentration is commendable; and until support is received which enables a larger number to be given a similar degree of attention even greater restriction in the field covered might frequently be regarded as advisable. It costs something to carry along almost any project. A certain overhead is indispensable in keeping it alive, although inactive, so that it may be picked up when desired. This often involves land, stock, and facilities, which mean a continued expense sometimes not greatly less than when the work is on a more active basis. And when the work is revived it may need to be redirected.

Every consideration urges the concentration of effort within the means of the station to make that effort efficient and constructive. But the expanding demands for aid make such concentration difficult or impracticable, and this continues to enforce the need of more liberal provision for research.

DUPLICATION

From time to time there is indication of a feeling that considerable duplication is taking place in the work of the experiment stations. The inference is that there continues to be a considerable amount of unnecessary repetition by different stations.

There is admittedly considerable duplication in the sense that the same or similar subjects are under investigation at different stations sometimes widely separated and sometimes in the same general region. Many of the leading subjects in the programs of the experiment stations are old ones. Varieties of fruits, vegetables, and other crops are being tested under new conditions, fertilizer experiments are being conducted on different soils under various cropping systems, feeding experiments are being made in the production of milk and meat, employing a wide range of farm-grown and commercial feeds. There are rotation series extending over long periods, farm management studies, culture and tillage trials with various crops, studies on the relation of stock and scion in fruit trees, experiments in the hogging off of crops, handling of flocks and herds, incubation of eggs, suppression of animal diseases, and the breeding of livestock. There are attempts to control common insects and plant diseases of long standing as well as newer enemies, there is progressive work on the handling of milk, the making of butter and cheese, and so on through the whole category of experiments.

However, these experiments are quite different from what they were a few years ago, both in purpose and plan, and they vary from one station to another. A certain amount of duplication is necessary in the practical range of experiments to meet local needs, and in more advanced lines repetition or continued study is essential for verification. To a great extent the status of work upon the familiar subjects of investigation reflects the state of knowledge which has developed with accumulated results.

Varieties are not being tested wholesale, as formerly, but largely in a restricted way and in connection with attempts at improvement in adaptation to a locality, or resistance to disease or some other quality. Wheat is being improved in Pennsylvania, Indiana, Kansas, Minnesota, California, Washington, and elsewhere. Oats are being bred for better strains in Maine, South Carolina, Ohio, New York, Michigan, Wisconsin, Iowa, Idaho, and other States. But it will hardly be maintained that this is duplication of an objectionable or unprofitable type. Recently a strain of oats produced in Maine showed qualities of advantage in Washington, and a variety of wheat originated in Kansas has spread over a wide region. Examples might be multiplied almost indefinitely. Crop improvement has been one of the large products of station work, and the result has fully justified the extensive work on which it has been based.

But what the casual observer evidently has in mind is duplication which is seemingly mere repetition, imitation without variation or any motive which contributes originality. Such an apparent going over of experimental fields already traversed is looked upon as unnecessary and unprofitable. And it would be if that proved to be the case when the circumstances were known. No one would attempt to justify it. But that the experiment stations are running along in a narrow groove, repeating one another's experiments without variation or to an extent which is unnecessary and unprofitable, is not evidenced by an intimate knowledge of their work the country over or a survey of their publications.

The history of experiment station work has taught caution in reaching practical conclusions and especially in applying them to a remote locality. Before transplanting such findings assurance will be desired both as to their applicability and practicability under the new environment. In this large country, representing such divergence of conditions, local applications must be based on experiments applicable to the section. Farmers are not content to be experimented upon themselves. They want general results or those derived elsewhere to be reduced to practice under their conditions.

Moreover, relatively little of the knowledge which now exists in agriculture is final or complete, any more than is that pertaining to electricity or the constitution of matter. Ideas regarding the nature of the atom have recently undergone very radical change on the basis of new investigation. So have those regarding the relative values of different foods and feeds, and the reason why some have superior qualities not accounted for by their composition or their action in mixed rations. Many workers are studying the vitamins as to their number, occurrence, special functions, and other qualities. What is already known about these substances which so long eluded scientists

is the product of many investigations and many minds. Progress will depend upon a continued multiplicity of effort.

Repetition in the making of experiments is essential to avoid error. Single trials or those covering a limited period rarely suffice. The results need to be verified, and to a certain extent they need to be tested at other stations. The Hatch Act anticipated this, and made it "the object and duty" of the stations "to conduct original researches or verify experiments." Naturally such verifications should be justified by the need, and this can not always be judged by the public. The seeming similarity of experiments is often explained on the ground that the subjects have not been exhausted and are being approached in different ways. The important thing is that the new investigation should begin where the previous work left off. If it repeats it in part it should be for the purpose of verifying a doubt and inaugurating something new. Again, it is frequently necessary to restudy, from time to time, problems which have been under investigation at an earlier date. As new facts are disclosed which throw different light on the subject it is often necessary to revive the work, and this may result in publications more or less similar to those of earlier days.

In the more advanced ranges of research there can be no danger of overduplication, provided each investigator embodies originality of ideas or methods in his attempt to get at the facts and their meaning. The more persons throwing their best constructive ability into the working out of a fundamental truth the better. One of them may succeed where others have failed to hit upon the right course or have overlooked some seemingly unimportant feature. This is the experience of all research in science where the attempt is to penetrate the unknown. The facts are elusive, and theories regarding them may be subject to revision.

In all investigation there inevitably will be experiments and inquiries which do not prove fruitful except in a negative sense. This is inherent in the nature of research. The investigator, like the searcher after gold, works over some ground which is unprofitable, but he does not do this purposely, and it is only as he continues to do so after he has discovered that ground to be unprofitable that he merits criticism.

To a considerable extent the suggestion of unnecessary duplication reflects a desire for more rapid advance, for a type of work which will make this possible. Sometimes the progress, from a practical standpoint, doubtless seems slow. Continuation is construed as duplication, ineffective because it does not reach more definite conclusions. It is doubtless true that some inquiries have proceeded about as far as they can until different means or a more analytic course is applied. More fundamental and far-reaching results will wait on more fundamental research. This, to a large extent, is the remedy for deferred conclusions, for seeming duplication.

RELATIONS WITH THE EXPERIMENT STATIONS

The Office of Experiment Stations maintained the usual close relations with the stations during the year, especially with those receiving the benefits of the Federal appropriations. In these relations and the supervision of the work under the Federal appropriations, there is no attempt at direction or control of research, or of

the lines it shall take; but the purpose is to insure that it is properly directed, is well considered at the outset, is not limited to unproductive repetition, and does not continue after it has ceased to make progress. The guiding purpose is to aid in securing favorable conditions for research, to stimulate investigators to their best efforts, to offer suggestion where it may be helpful, and to make the whole station enterprise as effective as possible, viewed as a national system which the Federal Government and the individual States are conducting in partnership.

The interest of the Federal Government is not confined to its contributions toward the maintenance of individual stations. It is not merely attempting to subsidize research in the States. It is endeavoring to assist in developing the most effective body of research possible for the benefit of a national industry, a body of knowledge whose application and value is rarely restricted by State boundaries. As an active partner the Government's interest extends to the point of developing favorable conditions to insure not only the proper use of the Federal funds but the employment of all available resources for research as effectively as possible. This cooperative view is expressed in the Hatch Act, whose purpose was "to aid" in the establishment and maintenance of experiment stations; and that this aid was not designed to be limited to the financial contributions is evidenced by provision for the relation of the department with respect to methods and results, the indication of important lines of inquiry, and the furnishing of "such advice and assistance as will best promote the purpose of this act."

In accordance with the usual procedure, each of the experiment stations was visited by a representative of the office during the year, its work and expenditures under the Federal funds examined in detail, and conferences held with the administrative head and the workers regarding the general progress and policy of the station. A revision of the classified list of projects carried on by all the stations was prepared and issued, to give timely information on the subjects under investigation at the various institutions.

The Adams Act is administered on the basis of definite projects, submitted by the stations and approved by the office in advance of the use of Federal funds upon them. A definite program of research is thus agreed upon at the beginning of each year, and if it is desired to inaugurate new projects during the year these are submitted and passed upon at any convenient time. The initiative in inaugurating research projects is left wholly to the individual stations, and a high degree of elasticity is preserved in arranging the annual program and using the funds.

In the examination of the projects submitted by the stations, effort is directed toward insuring that they are specific and limited in range, that the plan is adapted to the ends sought, and that the effort is upon a definite research plane. The requirements for carrying out the projects are taken into account, and suggestions are made for cooperation or for the addition of features which will place them on a competent basis. Attention is also given to the allotment of funds and the provision made for meeting the financial requirements of the projects. There has been some disposition to assign more projects to the Adams fund than could be properly supported

by it alone; and where other funds have not been available to adequately supplement the Federal funds the advisability of undertaking additional projects has been questioned.

As a rule the projects under this fund are supported in part from State funds, and in many cases the Adams fund contributes only a relatively small proportion toward the maintenance of the projects assigned to it. The stations could concentrate the Federal funds on a smaller number of undertakings and thus reduce the amount of supervision, but there has seemed no disposition to follow that course. The high grade of investigation for which the Adams fund stands has made many workers desirous of having projects under it and directors have welcomed the close supervision this entailed. Every effort is made to maintain the activities under this fund upon an energetic, progressive, and high research plane; and the influence which, in consequence, this fund has had on the development of research is far out of proportion to the amount involved. Similarly with the Hatch fund, care has been exercised that it should stand for substantial experimentation and investigation clearly distinguished from demonstration or random observation.

The growth of the stations and the steady development of their work furnishes a striking illustration of what may be accomplished through Federal leadership and stimulation without domination or attempt at control.

VISITATION OF THE STATIONS

A personal visit was made during the year to each of the continental stations receiving Federal funds by a representative of the Office of Experiment Stations. These visits as usual gave opportunity for a review of the work and expenditures of the year, conferences with members of the station staffs, suggestions regarding the work, and in general served to keep the office in personal and sympathetic touch with the organization, personnel, policy, and work of the stations. These visits were participated in by the chief (E. W. Allen), W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte. The office also continued to maintain close connection with the work and administration of the stations through extensive correspondence, review and approval of projects carried on under the Adams fund, examination of financial and other reports at the end of the year, review of publications relating to the work of the stations, and maintenance of up-to-date lists and records of station workers.

STATE LEGISLATION AFFECTING THE STATIONS

Comparatively few States passed any legislation that directly affected the stations during the year, as the following short summary shows.

In Indiana the Johnson Act, which was approved February 18, 1921, became effective July 1, 1922. This act gives the station two-fifths of a cent on each $100 of taxable property. It is estimated that this will yield permanently at least $200,000 per year.

In Michigan the State corporation tax law was declared constitutional by the State supreme court, adding largely to the funds of the

agricultural college for building and other purposes. At the beginning of the fiscal year the regulatory work previously done by the station, including the inspection of fertilizers, feeding stuffs, fungicides, and insecticides, as well as supervision of orchard, nursery, and apiary inspection, was transferred to the State Department of Agriculture.

In Nebraska a special session of the legislature, held in 1922, repealed the appropriation of $500,000 which had been made to the university to be used for building purposes. The supreme court of the State affirmed the law permitting the station to manufacture, buy, and sell antihog-cholera serum and virus.

In New Jersey acts were passed providing for investigations in the bee industry, with vegetables in northern New Jersey, and for studies on the root rot of peas.

In New York the legislature of 1922 authorized the New York State College of Agriculture and the New York State Experiment Station to initiate extensive investigations on the vegetable crops of Long Island. The college was authorized to purchase land, construct a laboratory and greenhouse, and to employ, besides labor, a special investigator in vegetable gardening. The experiment station was authorized to employ a special investigator in diseases of vegetable crops and one in insects attacking vegetables.

The Ohio station was placed under a new board of control, consisting of seven trustees of Ohio State University and the State director of agriculture.

In Texas an act was passed abolishing the separate governing board of the substations and transferring its functions to the board of directors of the Texas Agricultural and Mechanical College.

STATE APPROPRIATIONS

All of the experiment stations except one received some State support during 1922, although in several cases the amount was small or designed primarily for regulatory functions. Several stations received appropriations for the first time in many years.

A large number of the stations are now receiving liberal State appropriations. During the year covered by this report the stations in California, Illinois, Minnesota, and Ohio received over $300,000 each from the State; those in Indiana, Iowa, Texas, and Wisconsin between $200,000 and $300,000 each; and 11 other stations had between $100,000 and $200,000 each from this source. Six stations each received $10,000 or less. It should be noted, however, that the State appropriations do not always represent amounts devoted strictly to investigation, as in many cases they include funds appropriated specifically for work of a regulatory or similar nature. They include in many cases also money for the erection of buildings, the purchase of land, the support of branch stations, overhead expenses, and the like.

There were notable increases in State appropriations for the experiment stations during the year, few stations reporting no increase or a decrease. The total net increase was $1,278,634. The increases and decreases in State appropriations during the year as compared with the preceding year are given in the following table:

TABLE 1.—*Increases, decreases, and total amounts of State appropriations for the experiment stations, 1922*

Station	Increase	Decrease	Total
Alabama			$34,500
Arizona	$17,250		66,532
Arkansas	13,871		56,946
California	232,622		380,000
Colorado	34,357		109,686
Connecticut State	22,922		61,122
Connecticut Storrs		$10,322	17,500
Delaware	5,000		15,000
Florida	50,000		55,000
Georgia	11,715		11,766
Idaho		11,225	10,033
Illinois	170,294		310,294
Indiana	65,750		215,983
Iowa	109,500		250,000
Kansas	15,000		97,000
Kentucky			50,000
Louisiana			50,000
Maine	16,146		31,146
Maryland		4,404	49,624
Massachusetts	15,953		99,153
Michigan		107,013	90,000
Minnesota	87,943		306,943
Mississippi	7,548		102,377
Missouri	6,885		42,087
Montana	55,073		134,469
Nebraska	20,018		71,742
Nevada	1,737		1,878
New Hampshire	5,000		5,000
New Jersey	23,794		142,957
New Mexico			7,500
New York Cornell		9,155	183,474
New York State	12,525		198,355
North Carolina	59,187		162,737
North Dakota	48,226		151,334
Ohio	45,276		310,641
Oklahoma	500		10,500
Oregon	14,794		107,544
Pennsylvania	36,436		36,436
Rhode Island	7,359		9,052
South Carolina	7,987		57,987
South Dakota		40	14,420
Tennessee	1,391		33,295
Texas		18,984	201,535
Utah		3,345	50,124
Vermont			
Virginia	6,948		45,298
Washington	16,914		104,675
West Virginia	15,213		120,000
Wisconsin	5,000		215,000
Wyoming	12,500		12,500
Total	1,278,634	164,488	4,901,145

ADDITIONS TO BUILDINGS AND EQUIPMENT

At the Arizona station a gin for small samples of cotton and a 10-saw gin for larger amounts were purchased. A screened garden for cotton experiments was constructed on the campus. An appropriation of $12,500 was made for the construction of a new poultry plant, and five blocks of land were secured, costing $5,000. Twelve other blocks near the university were also secured. At the Sulphur Springs Valley Dry Farm four corrals were built. At the Prescott Dry Farm the barn, two feed corrals, and a modern farm dwelling costing about $4,800 were completed. A small two-room frame house was also built at the Yuma Mesa Farm, and 4½ acres were added to the farm at a cost of $2,250.

At the Arkansas station a new greenhouse costing $2,800 was completed and occupied. A hog house costing $2,600, a beef cattle shed costing $1,000, and a seed and fertilizer house costing $1,600 were

completed. Four laborers' cottages, costing $1,000 each, were built on the recently acquired farm. The horticultural department added about $1,000 worth of improvements.

At the California station the new dairy industry building, costing with equipment approximately $225,000, and the new building for pomology, viticulture, and botany, costing $120,000, provided for by the last legislature for the Branch College of Agriculture at Davis, neared completion. It was expected that this would release the old horticultural building for work in chemistry and zoology and the former creamery building for soil technology and irrigation. Further improvements at Davis included an agronomy warehouse, equipped with seed-cleaning machinery; a modern fruit-packing and cool-storage house; a new wool laboratory equipped with a gas-heated drier; a modern electrically operated conditioning oven; and an irrigation field laboratory equipped to test and demonstrate practically all of the standard irrigation appliances used in practice. A group of ranch buildings, including dining hall, sleeping quarters, and implement shed, was also added; a new water tank was erected and 370 acres provided with underground irrigation pipes. The Citrus Experiment Station at Riverside was improved by fencing, installation of a separate domestic water system, and extension and improvement of the irrigation system on the experimental plats. An appropriation of $129,000 was made to complete the purchase of land for the southern branch of the College of Agriculture. On the Hunt tract, recently acquired by the university, a pumping plant was installed. At Berkeley a laboratory for the semicommercial production of canned fruits and vegetables, fruit sirups, jellies, candied fruits, vinegar, vegetable oils, and other similar food products was fitted up with canning and preserving equipment to the value of $5,000.

At the Florida station a brick laboratory to cost $12,000 was begun at the citrus branch station at Lake Alfred, also a residence for the superintendent to cost $3,739. At the tobacco station at Quincy, 23 acres of land costing $3,500 was purchased and a laboratory building to cost about $13,021 partly completed.

At the Georgia station provision was made for rebuilding one of the greenhouses to be used by the department of botany for plant-disease work. A small summerhouse was constructed for farmers' clubs and picnic parties.

At the Illinois station the legislature appropriated $500,000 for the first unit of an agricultural group of buildings and construction was begun during the year. A horticultural field laboratory costing $260,000 was completed.

At the Indiana station an additional farm of 120 acres near the university was bought for experiments with fruit varieties, orchard management, and the production of truck crops, and the purchase of a suitable tract for experimental work with livestock was authorized. An incubator cellar and a hospital were built on the poultry farm. The 40-foot extension of the dairy barn to accommodate 20 additional cows for experimental purposes was completed. The construction of a new home economics building was commenced during the year.

At the Iowa station a new hog barn, a judging pavilion costing $20,000, a number of poultry buildings, including rearing and laying houses, and a new building to house educational and research work

in agricultural engineering, costing $75,000, were completed and occupied. Twenty thousand dollars became available for a sheep barn and pavilion. A fertilizer house was built on the agronomy farm for the soils section at a cost of about $2,500, a frame building for feed storage was erected on the animal husbandry farm, and a cold-storage laboratory for pomology was installed with respiration equipment. A new 178-acre farm purchased for the animal husbandry department was fenced and graded, and the forestry nursery was increased in acreage.

At the Kansas station construction was begun on an addition to the agricultural building to cost $275,000, which will house the departments of agricultural economics, dairy husbandry, and poultry husbandry; and construction of a $25,000 annex to the east wing of the agricultural building for use as a meat laboratory was in progress. Two hundred and fifty acres of native pasture land was purchased for the use of the animal husbandry department, and a weighing outfit was installed at a cost of $1,000. The greenhouse was repaired. A machine shed was built at the Fort Hays station at a cost of about $4,000.

At the Louisiana station construction of a new hog barn and of a cattle barn at the new agricultural college site was in progress. Several pieces of scientific apparatus were added to the equipment.

A new chemical laboratory, to cost $300,000 and to house some station activities, was commenced at the Massachusetts Agricultural College. The Brooks farm of 60 acres was purchased for $15,000 and will be used for tobacco and onion studies. The station has come into possession of 50 acres at Waltham for market garden work.

At the Minnesota station the construction of a new dairy building to cost about $250,000 was authorized.

At the Missouri station a new agricultural building costing $200,000 was under construction. This building will house the offices of the dean and director, and the agricultural editor, the mailing room, agricultural library, seminar room, and the departments of soils, rural life, and poultry. The construction of a new beef cattle barn for 100 head of cattle, with winter feed, to cost $25,000, was started. The third floor of the horticultural building was remodeled at a cost of $4,000, and the basement of the biology building was finished at a cost of $10,000, to be occupied largely by the departments of zoology and botany. Material additions were made to the poultry plant. Various other buildings were being constructed at the university, which will have a bearing on the station work.

At the Montana station the old barracks building was remodeled for agricultural engineering at a cost of $10,000. New buildings under construction at the college included a biology building costing $175,000, an engineering building costing $250,000, shops costing $100,000, a gymnasium costing $225,000, and a central heating plant to cost $150,000, and $250,000 was appropriated for furnishing and equipping the new buidlings.

At the Nebraska station a new cattle barn costing $30,000 was provided for, the dairy department to take over the old barn. At the Valentine substation, an open shed, a single-unit poultry house, and a new corral fence were constructed.

At the Nevada station 3,500 feet of dog-proof fencing was put up and an open shelter for lambing for the station flock was built.

At the New Jersey stations a poultry husbandry building costing $85,000 was practically completed during the year. A new horticultural building was completed in July, 1921. The 1922 legislature appropriated $150,000 for a new dairy and animal husbandry building and $20,000 for equipment of the poultry building. Other buildings added included a new piggery, a concrete garage, and a storage building.

At the New Mexico station the old greenhouse was rebuilt and a smaller poultry house was added to the poultry farm.

At the New York Cornell station a new dairy building was in process of erection, nearly $400,000 being available for it in addition to over $200,000 for equipment. Some smaller new structures were added, including a cold-storage plant for pomology and an insectary with a glass laboratory, and a field was secured for plant breeding.

The New York State station equipped a complete constant low-temperature room for ice-cream investigations.

At the North Carolina station a new building for the State department of agriculture, to cost about $375,000 with equipment, was being constructed at Raleigh, and will be used in part for station work. A new poultry plant, dairy equipment, and three cottages for labor were added to the Mountain Branch station at Swannanoa. A new sweet-potato storage house with a pecan-curing room was built at the Edgecomb Branch station at Rocky Mount. At the Blackland Branch station at Wenona a new swine plant and a cottage for the foreman were built.

At the North Dakota Agricultural College a new agricultural building was in process of erection, which is primarily for college use but will release other space for station use. New barns were erected at the Hettinger and Langdon substations.

A new dairy barn at the Oklahoma station was occupied.

At the Oregon station the completion of a new building for the school of commerce made it possible to secure additions to station laboratories for bacteriology, horticulture, entomology, farm crops, and soils. Considerable equipment was added to the central and branch stations, including a new cottage, remodeling of the stock barn, and the extension of city water and electric lines at the Union branch station.

A new beef-cattle barn was being erected at the Pennsylvania station. Complete gas-analysis apparatus was installed at the Institute of Animal Nutrition.

At the Rhode Island station the new agricultural and administration building was dedicated during the year.

In South Carolina a new silo for beef-cattle experiments was built at the college and also one at the coast station.

At the South Dakota station 15 acres of additional land was provided for the horticultural department.

At the Tennessee station a battery of 12 tanks was added to the lysimeter equipment, making this probably the most complete in the country.

The Texas station installed a complete wool-scouring plant.

At the Utah station a 10-acre tract of land was purchased for pasture experiments. The water measurement and pumping laboratory was completed. An electrically heated Kjeldahl digestion and dis-

tillation outfit of six units was installed in the soil-survey laboratory. New apparatus was added to the station.

At the Virginia station a fully equipped barn partly paid for by the college was provided for experimental work with dairy cows. A battery of lysimeters was completed. A barn and a granary were built at the Bowling Green station.

At the Washington station a beef-cattle barn and a sheep barn were completed. Two cement silos were constructed in connection with the cattle barn and a wooden silo in connection with the sheep barn. These are for the college of agriculture, but they will help in the investigational work. The old cattle barn was remodeled for the dairy herd. At the Prosser branch station a silo, corrals, and feeding lots for sheep and cattle were constructed.

At the West Virginia station a new dairy barn estimated to cost about $30,000 was in process of erection.

At the Wisconsin station a beef cattle barn costing about $16,000 was erected during the year.

At the Wyoming station about $4,000 worth of additional livestock was purchased for the farm.

CHANGES IN PERSONNEL

During the fiscal year there were six changes in directorship of the stations. At the Arizona station J. J. Thornber succeeded D. W. Working. W. R. Dodson returned to the Louisiana stations as director, succeeding W. H. Dalrymple. R. W. Thatcher succeeded W. H. Jordan as director of the New York State station. C. G. Williams, who had been acting director of the Ohio station since the retirement of Director C. E. Thorne, was made director in August, 1921. F. S. Harris resigned as director of the Utah station and was succeeded by William Peterson. H. G. Knight was elected director of the West Virginia station.

At the Alabama station E. F. Cauthen resigned as agriculturist and F. W. Parker was appointed soil chemist.

The most important changes at the Arkansas station included the appointment of S. J. Schilling as associate veterinarian, A. D. McNair as specialist in farm management, F. A. Wirt as head of the department of farm machinery. W. J. Baerg returned from leave of absence as head of the entomology department.

H. J. Webber returned to the California station in charge of work in citriculture, and C. B. Hutchison was made professor of plant breeding and director of the branch of the College of Agriculture at Davis. Other appointments included A. J. Winkler, associate in viticulture, and J. P. Conrad, associate in agronomy.

At the Colorado station I. G. Kinghorn was appointed editor.

W. L. Slate, jr., was appointed vice director of both of the Connecticut stations. G. H. Chapman was placed in charge of the tobacco work at Windsor.

At the Florida station W. E. Stokes was appointed in charge of forage crop investigations, and W. B. Tisdale was put in charge of the Quincy tobacco station.

At the Georgia station J. A. McClintock, plant pathologist, resigned to become associate plant pathologist at the Tennessee station.

H. P. Davis, head of the dairy department, resigned to go to the Nebraska station and was succeeded by F. W. Atkeson. C. Wakeland was appointed field entomologist to succeed R. H. Smith.

A number of changes were reported from the Illinois station. Those involving the more important positions included the appointment of A. H. Ruehe as head of the dairy department, H. P. Rusk as head of the animal husbandry department, and L. E. Card as head of the poultry husbandry department. C. F. Hottes was appointed consulting plant physiologist in the agronomy department; A. L. Whiting, chief in soil bacteriology, resigned. G. E. Fager was appointed associate in plant breeding. H. S. Grindley, chief in animal nutrition, returned from sabbatical leave, and J. A. Detlefsen was granted leave of absence. A number of assistants were appointed during the year.

At the Iowa station W. H. Stevenson, chief in agronomy, was absent during the year as American delegate to the International Institute of Agriculture at Rome. H. D. Hughes, chief in farm crops, and J. M. Evvard, chief in swine and beef-cattle investigations, were on leave of absence. A. C. McCandlish, chief of the dairy section, resigned, and F. F. Sherwood was appointed assistant chief of this section. C. J. Drake was appointed chief of the entomology department.

The more important changes at the Kansas station included the appointments of N. E. Olson as associate in dairy husbandry, succeeding O. W. Hunter, and L. C. Aicher, superintendent of the Fort Hays branch station, succeeding H. L. Kent. In addition, there were a number of appointments and resignations of assistants in various departments.

At the Louisiana stations W. L. Owen was appointed bacteriologist at the sugar station. G. D. Cain, in charge of the North Louisiana station at Calhoun, resigned and was succeeded by Sidney Stewart. B. Szymoniak was appointed in charge of the fruit and truck station at Hammond.

At the Maryland station DeVoe Meade was transferred from the college to part-time station work in animal husbandry.

The changes at the Massachusetts station included the resignation of G. H. Chapman as research plant physiologist, his place being filled by transferring P. J. Anderson from the instruction staff. A. P. French was appointed investigator in pomology and H. D. Goodale resigned as research professor in poultry husbandry.

At the Michigan station E. C. Foreman succeeded C. H. Burgess as head of the poultry department, and O. E. Reed was appointed head of the dairy department. P. S. Lucas was appointed research associate in dairy manufacture, and C. F. Huffman research assistant.

In addition to the change of directorship at the Minnesota station, mentioned above, J. H. Beaumont succeeded M. J. Dorsey in charge of fruit breeding, and P. F. Sharp, associate in milling and baking, resigned.

At the Mississippi station H. B. Brown resigned as plant breeder and was succeeded by J. F. O'Kelley.

Although a number of changes were reported from the Missouri station, most of these were among the assistants. The most important change was the appointment of E. L. Morgan in rural sociology.

The principal changes at the Montana station included the appointment of Clyde McKee head of the department of agronomy, and of F. M. Harrington head of the department of horticulture. There were numerous changes among the assistants.

Changes at the Nebraska station included the appointment of M. J. Blish as head of the chemistry department, and of H. P. Davis as head of the dairy department. F. D. Keim, of the agronomy department, was transferred to the college. A number of changes occurred among the assistants.

At the New Jersey stations W. C. Thompson was appointed head of the poultry department and R. R. Hannas superintendent of egg-laying contests. W. Rudolfs was appointed biochemist.

New appointments at the New Mexico station included J. H. Bardsley in the poultry department, succeeding F. E. Uhl, and C. W. Botkins as chemist, holding also the office of State chemist. The resignations included Luther Foster in the animal husbandry department and L. S. Brown, nutrition chemist, the latter succeeded by H. W. Titus.

At the New York State station G. A. Smith resigned from the dairy department and was succeeded by A. C. Dahlberg. In addition to these there were various changes in the staff of assistants.

At the Ohio station E. Secrest, of the forestry department, was appointed associate director. G. Bohstedt was appointed chief of the animal husbandry department and D. C. Kennard associate chief. J. H. Gourley was appointed chief of the horticultural department. W. K. Greenbank suceeded C. M. Baker as editor. C. W. Montgomery, chief in farm management, was made also superintendent of county farms, succeding J. P. Markley in the latter capacity. There were a number of appointments and resignations among the assistants.

The only important change at the Oregon station was the resignation of James Dryden, head of the poultry department, who had been on leave of absence. H. G. Miller, associate chemist, was absent on leave.

The Pennsylvania station lost two important members of its staff by death during the year—William Frear, head of the department of agricultural chemistry and vice director, and H. P. Armsby, director of the Institute of Animal Nutrition. Doctor Frear was succeeded by R. A. Dutcher. Other changes on the staff involved assistants only.

At the Rhode Island station a department of marketing and economics was established and H. B. Hall was appointed in charge.

At the Tennessee station G. M. Bentley was transferred entirely to instructional work, being succeeded as station entomologist by S. Marcovitch. J. A. McClintock, of the Georgia station, was appointed associate plant pathologist.

Changes at the Texas station included the appointment of J. L. Lush as animal geneticist. H. B. Parks succeeded L. R. Watson as apiculturist. The resignations included E. W. Geyer as agronomist and A. B. Cox, chief of the division of farm and ranch economics.

At the Utah station, in addition to the change in the directorship, I. M. Hawley was appointed entomologist. T. H. Abell was placed

n charge of the horticultural department on the resignation of M. J. Merrill. G. Wilster was appointed associate in dairy husbandry. Miss Blanche Cooper resigned as associate in human nutrition.

At the Washington station E. V. Ellington succeeded E. G. Woodward as head of the dairy department.

In addition to the change in the directorship of the West Virginia station, already noted, M. J. Dorsey succeeded J. H. Gourley as head of the horticultural department. B. H. Hite, head of the chemical department, died in October, 1921.

PROJECTS IN 1922

The total number of projects carried on by the State experiment stations in 1922 was 5,156, an average of about 103 per station, a slight increase over the previous year. Of these, 490 projects, or nearly 10 per station, were conducted under the Adams fund, a slight decrease for the year. Of the total number of projects, 56 were purely administrative, control, or regulatory. Subtracting these leaves 5,100 devoted to research and experimentation, to which may be added 140 projects carried on by the experiment stations in Alaska, Guam, Hawaii, Porto Rico, and the Virgin Islands, giving a total of 5,240 research projects.

The list shows an increase of 385 in the total number of projects during the year. This increase is probably not due wholly to an extension of the work, but partly to splitting up of more generalized projects into those of a more specific nature and to the more general use of the project system of recording the work.

An analysis of the projects shows little relative change as compared with last year's record. Field crops leads with a total of 1,611 projects, corn being the subject of 183, followed by potatoes with 153 and wheat with 143. The second largest group in the list is horticulture with 904 projects, under which the leaders are apples with 118 projects, fruits (general) with 61, and vegetables with 58. Plant pathology comes third in the list with a total of 452 subjects, the largest subheads being potato diseases with 51, cereal diseases with 34, and apple diseases with 32 projects. Economic entomology follows with a total of 412 projects, the larger subdivisions of which were bees 45, insecticides 39, and miscellaneous 20. The next largest division is soils with 310 projects, including soil fertility 46, soil flora 38, and soil types 29.

The subject of veterinary medicine includes 194 projects, fertilizers 193, rural economics 186, and rural engineering 162. The number of projects on swine is 180, dairy cattle 176, poultry 170, beef cattle 8, and sheep 74, while there are 111 on feeding stuffs and animal nutrition and 105 on genetics.

The largest increases over the previous year were in horticulture with 96 and fertilizers with 52 more projects. There was a slight falling off in the number of projects under foods and human nutrition, feeding stuffs and animal nutrition, chemistry, and bacteriology.

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SOME RESULTS OF STATION WORK

By E. R. Flint

The following is a résumé of some of the outstanding results of station work during the year, the purpose of which is to give a general view of the progress made.

SOILS AND FERTILIZERS

Rare constituents of soils.—The universal distribution of manganese in soils and plants is indicated by investigations reported by the Kentucky station. Apparently the manganese performs an important function in plant nutrition and is essential in small amounts to the growth of the higher plants. Manganese was found to be toxic to plants in acid soils, but the toxicity was corrected by liming. Colorado soils contain considerable amounts of barium, strontium, lithium, and other comparatively rare or unusual elements. The Colorado station found that when grown on such soils, alfalfa was relatively rich in barium and strontium, but poor in lithium; tobacco contained barium and lithium, but little strontium; and potatoes contained strontium and lithium, but no barium; whereas corn contained all three, as well as considerable titanium.

Soil colloids—The Missouri station reported a method of separating the colloids by a high-power centrifuge. Analysis of the material so obtained showed the main constituents to be SiO_2 46 per cent, Al_2O_3 24 per cent, Fe_2O_3 7 per cent, and water 20 per cent. Further studies showed that the material is not made up of appreciable amounts of the free oxids, but is largely a highly hydrated complex alumino-silicate, which may be considered the end product of the weathering of certain soil materials in humid, temperate regions. The material was found to flocculate more readily with acid sodium phosphate than with lime. In experiments at the Utah station with a series of soils ranging from sands to light clays, comparable vapor pressure moisture curves were found to maintain nearly constant ratios of hygroscopic water over a wide range of vapor pressure, and the results are believed to confirm the theory of the "colloid-coated particles" of English investigators. It was found that soluble salts may flocculate at one concentration and deflocculate at another.

Soil moisture.—The Nebraska station found moisture penetration to be much slower in a thoroughly dry soil than in a moist one. Capillary rise and consequent loss of moisture from the surface of dry-land soils, where the water table lay at a considerable depth was very slight. Lateral or downward movement of moisture in soil was very slight after the first or second day following rains. The chief agency in the exhaustion of soil moisture is the crop growing upon it. In tillage tests it was found that in soils where the available moisture was the limiting factor, summer tillage and early fall plowing served best to store and preserve the soil moisture; but summer tillage did not return a profit with corn or with grain crops except in those years when yields from ordinary practices were considerably depressed by lack of moisture.

Experiments at the Minnesota station showed that rolling a sand soil or the addition of crop residues or of peat decreased evaporatio

and increased water retention in the soil. Addition of lime did not increase the water-holding capacity to any appreciable extent.

The use of water by wheat and other small grains on dry land was found by the North Dakota station to amount to about 0.16 inch per day from stooling to maturity.

The Washington station found that under drought conditions an abundant supply of nitrate nitrogen, with a consequent heavy yield of straw, tended to reduce the yield of grain. It therefore appears that during a season of drought it is more important to center tillage operations on saving a maximum supply of soil moisture than on developing nitrates. Tillage experiments showed that the earliest possible spring preparation of the summer fallow led to a greater accumulation of nitrates than later preparation. It also showed that very early preparation did not conserve appreciably more moisture than a later one, if the latter preceded the active growth of volunteer grains and weeds.

Soil erosion.—In experiments at the Missouri station on a soil having approximately a 4 per cent slope, the greatest erosion and accompanying loss of nitrogen occurred in shallow plowed continuously cultivated soil, the least in soil under continuous sod. Intermediate rates of erosion in descending order were observed in case of continuous corn culture, continuous wheat culture, and a rotation of corn, wheat, and clover. The estimated rate of erosion in case of continuous sod was 7 inches in 2,336 years with an insignificant loss of nitrogen. The same soil plowed 4 inches deep and cultivated eroded at the rate of 7 inches in 25 years.

Soil acidity.—Studies at the Indiana station indicated that the beneficial action of acid phosphate in preventing injury to plants by soluble aluminum salts in acid soils was not altogether due to prevention of absorption of the aluminum salts by the plant, but partly to some action of the phosphorus on the aluminum in the plant.

The Michigan station found soil components, separately or collectively, to be amphoteric in nature, the degree of acidity in soils being proportional to the ratio between the active bases and acids, and not to the excess quantity of active acids. The degree of acidity of soils did not correlate with the quantity of base required for neutralization (lime requirement), the latter depending upon the excess of active acids over active bases. The reaction of soils appears to depend upon the quantity relationship between hydrogen ions and hydroxyl ions in the soil solution, a relationship which can be determined by means of an indicator dye (bromthymol blue) and the use of pure water to obtain a soil extract.

The New Jersey stations found that when calcium nitrate was used in connection with ammonium sulphate, the nitrate ion was absorbed, leaving the lime to counteract the acidity; with ammonium sulphate alone, the ammonium ion was absorbed, the remaining sulphuric acid thus increasing the acidity. When nitrogen was present as ammonium and nitrate in the same solution, the plant took up first the ammonium nitrogen and then the nitrate nitrogen.

Studies at the Oregon station showed that in a soil whose crop-producing power had been depressed by the application of lime, the pH value was 7 or greater. The growth of plants appeared to be more closely associated with the ionization than with the titratable acidity.

The Rhode Island station found that Thomas slag, acid phosphate, and ground bone were especially active in reducing soil acidity. Acid phosphate did not increase acidity as is commonly believed. All potash salts slightly reduced acidity, kainit being most active in this respect. Leguminous cover crops tended to increase the soil acidity appreciably, but nonlegumes slightly decreased it. If the pH value is kept down to 4.5 to 5, weeds may be kept out of lawns.

At the Washington station an examination of a large number of acid soils from regions where the precipitation varied from 7.5 to 21.5 inches showed that the percentage of nitrogen and carbon increased with the precipitation; but the ratio of 1:12 remained practically constant for all soils, this being about the same as for soils from humid regions.

Soil alkalinity.—Experiments at the Arizona station showed that practically all chemicals that react to sodium carbonate reduced the toxicity of black alkali. Partial neutralization was nearly as effective as complete neutralization. Neutralization seemed to give better results than elimination by leaching alone. By the combined action of gypsum and manure the productivity of black alkali soil has been sucessfully brought up to that of ordinarily fertile soils. Tepary beans did not germinate with 0.25 per cent of black alkali. With 0.2 per cent they germinated but died. The limit was found to be 0.15 per cent of sodium carbonate. Cotton plants also died with 0.25 per cent. The limit was 0.2 per cent for most crops tested, especially wheat and barley, although the former is somewhat more resistant than the latter. With Mexican June corn, 0.1 per cent was the limit. Plants are more resistant on heavier soils than on sand.

In experiments at the Oregon station an application of 500 pounds of sulphur resulted in the removal of 65 per cent of alkali in the drainage, and applications of gypsum and lime removed 60 per cent. A smaller quantity was removed by aluminum sulphate. The Utah station found, in general, that the addition of more than very small amounts of other soluble salts increased the toxicity of sodium carbonate in an alkali soil. Applications of manure, gypsum, and small amounts of nitrates produced some improvement.

Lime and liming.—The Virginia station obtained good results in crop production with a lime-magnesia ratio of 1:1; but when the ratio became 1:2 yields were depressed. The Iowa station found a close relation between the amount of carbon dioxid given off by the soil and its lime requirements. The Delaware station found all forms of lime to be equally valuable in decomposing green manures as measured by the amount of carbon dioxid given off. Magnesium limestone, as well as ordinary limestone in a fine state of subdivision, was especially active when first applied, but eventually the amount of carbon dioxid given off was about the same for all forms of lime.

The Iowa station found gypsum applied to various soils of the State to be of little or no economic value in any case. The Tennessee station found that the initial toxicity to seedlings, due to noncarbonate residuals from precipitated magnesium carbonate after its disintegration and fixation in the soil, was followed by a period during which a favorable response was obtained. The initial results dependent upon the lime-magnesia ratio were at variance with those secured later.

The residual effect of one crop on another is, according to the Rhode Island station, largely a question of soil reaction and can be largely corrected by liming.

Soil bacteriology.—In experiments at the Colorado station fixation of nitrogen by Azotobacter took place within narrow limits of soil reaction and stopped when the pH value reached 5.7, the optimum being 7.5. Plowing under of millet depressed nitrogen fixation in the soil, as did application of sulphur. Accumulation of nitrate nitrogen increased rapidly as long as the soil was alkaline. Sulphur and ammonium sulphate depressed nitrification. Of 481 soils examined at the Kansas station only 199 contained Azotobacter. The critical point for nitrogen fixation was found to be pH 6. Very few soils more acid than this contained Azotobacter, and very few less acid than this failed to show the presence of the organism.

At the Idaho station alkali salts were found to stimulate bacterial activity in some soils, while in others they were distinctly toxic. Sodium chlorid and sulphate decreased ammonification, but sodium carbonate increased slightly both ammonification and nitrification in some cases.

In studies at the Utah station various salts, including carbonates, chlorids, sulphates, and nitrates of sodium, magnesium, calcium, and iron, applied to soils in small quantities, increased the bacterial activity, as manifested by increased production of ammonia, nitrates, soluble phosphorus, and nitrogen fixation. The nitrifying organisms were more sensitive to alkali than the ammonifying, which tolerate large quantities of alkali. The salts apparently form compounds with the protein of the organisms other than those normally occurring in living protoplasm, thus making them incapable of functioning normally. Osmotic changes also appear to play a part in bacterial activity. Some alkali soils appear to be unproductive as a result of the action of the salts upon the flora and only indirectly through toxicity to the higher plants. The optimum moisture content of the soil for maximum bacterial activity, stated in water-holding capacity of the soil, was found to be 60 per cent for ammonification and 50 to 60 per cent for nitrification, this holding true in all kinds of soils. These are also near the optimum content for the higher plants.

At the New Jersey stations organic matter stimulated the development of all groups of soil microorganisms studied. Lime increased the number of bacteria and to a still greater extent the Actinomycetes, but caused a relative decrease in fungi. The continued use of ammonium sulphate without lime resulted in a decrease of bacteria and a much greater decrease in Actinomycetes, with a relative increase in the number of fungi. A reaction equivalent to pH 5 to 5.2 was found to prevent the growth of Actinomycetes in liquid cultures, and pH 4.8 to 5.2 was the limiting point for their growth in soils. When organic matter in the form of manure or green manure was applied to the soil, the number of Actinomycetes increased rapidly. The use of lime produced very favorable conditions for the development of Actinomycetes.

In experiments at the Washington station the plowing in of straw just before seeding wheat resulted in a decrease in available nitrogen in the soil and in reduced yields of an inferior quality. The greatest reduction in nitrates and yield resulted where the moisture

content of the soils was lowest. There was no reduction when the moisture content was kept at the optimum for nitrification. In tests at the Idaho station of the effect of various forest materials on ammonia and nitrite accumulation in the soil, it was found that the greatest reducing effect occurred with cedar sawdust and needles, ranging from 5 to 60 per cent. Nitrogen fixation was reduced by some of the tree products tested and practically eliminated by others.

The Missouri station found that when the surface soil was covered an inch deep with straw, nitrification was inhibited in the first 7 inches, and that cultivation lessened the amount of nitrates in the first 7 inches in the same depth of soil. The New York Cornell station found that growing corn stimulated nitrification in the early stages and retarded it later.

Soil inoculation.—At the Missouri station samples of soil in which soy beans and red clover had grown with abundant nodules were subjected to various treatments for four years, including exposure out of doors, but with protection from contamination, and drying in the sunlight and in the dark. After the treatment all of the samples still had enough viable bacteria to produce good inoculation. The test indicated that soil once inoculated for soy beans and red clover need not be reinoculated when these crops are grown in a four-year rotation. Tests at the Wisconsin station of cultures from nodules of alfalfa, soy beans, and clover showed that these lost their power to inoculate their host plants in 75 days when the soil was distinctly acid, but retained their vitality much longer in neutral soils.

Sulphur.—The Illinois station observed that the amount of sulphur added in rainfall ranges from almost negligible quantities to considerably more than total removals in crops and drainage water. The variation in soil sulphur runs, in general, parallel to those in organic carbon.

At the New Jersey stations two sulphur oxidizing organisms were isolated in pure culture, one of which is new. One rapidly oxidizes elementary sulphur and to some extent thiosulphates and sulphids, with quantitative formation of sulphuric acid. The second organism oxidizes elementary sulphur to a limited extent only, and acts mainly on thiosulphates and sulphids. The acid formed renders rock phosphate soluble, the process being most active when the reaction of the medium is between pH 2.6 and 3.2. The addition of sulphur to alkali soils results in reducing the alkalinity.

The Oregon station found that soils from different parts of the State oxidized sulphur as rapidly as would be required for maximum crop production. There was no apparent relation between the total sulphur content and the sulphur-oxidizing power of the soil. The application of sulphur brought about an increase in the sulphur-oxidizing power by making the soil a more favorable medium for the growth of sulphur-oxidizing organisms. Temperature and moisture of the soil were found to be important factors in the rate of oxidation, although oxidation was active even in an air-dry soil.

The Tennessee station found that all forms of calcium and magnesium materials tend to accelerate the outgo of sulphur from surface soils, even in the case of light additions. Increasing the amounts of native limestone and magnesite produced no consistent variation from the effects induced by the lighter treatments, but increasing the

amount of dolomite applied caused a marked increase of sulphate produced. This was also true of magnesium oxid, but not of calcium oxid. The power of the subsoil to stop the outgo of both basic and radical ions was overcome by the more soluble magnesium salts. Magnesium, especially in large quantities, was found to accelerate the generation and leaching of sulphate sulphur.

The Washington station found that applications of elemental sulphur at the rate of 160 to 500 pounds per acre caused an accumulation of soil nitrates, whereas 1,000 pounds caused a decrease. Nitrate accumulation was decreased by the use of sulphur on manured soils. The rate of oxidation of the sulphur was affected but little by the addition of manure.

Nitrogen.—The Montana station found that nitrogen was made available slowly in undisturbed virgin soils, but more rapidly under summer fallowing, cultivation, or manuring. An intermediate rate was found in soils cropped every year to small grains. The rate was increased by adding lime to soils showing an acid reaction.

The Pennsylvania station, after 40 years of continuous cropping, found the percentage losses of nitrogen applied to be as follows: With manure 63, nitrate of soda 58, dried blood 59, and sulphate of ammonia 100. The sulphate of ammonia plats showed a pH value of 4.47, dried-blood plats 4.61, nitrate of soda 5.14, and manure 5.28. Plats receiving only potash and phosphorus showed a pH value of 5.15.

In lysimeter experiments at the Tennessee station there was no recovery of nitrogen in the drainage of deep cylinders. Where there was recovery, the nitrogen was in the form of calcium and magnesium nitrates. There was no decline in the nitrogen content of the cropped as compared with the uncropped soils.

At the Texas station the correlation factor between the nitrogen content of the soil and the nitrogen taken up by the crop was found to be 0.653 ± 0.029. The ratio between the amount of nitrogen taken up by the first crop and the amount of nitrates available in the soil was 0.708 ± 0.025, and between the nitrogen removed by the crops and the decrease in nitrification of the soil, 0.68 ± 0.029.

Phosphates.—At the Wisconsin station, in pot cultures with alfalfa, it was found that some soils that show a rather high phosphorus content respond to the addition of phosphates. In some soils there was no response to calcium or potassium until phosphate was added. The studies indicated that the less acid the sap of the plant the greater is its power to draw phosphorus and potash from dilute solutions.

In a test, at the Arkansas station, of rock phosphate of different degrees of fineness both corn and oats were somewhat earlier with the finely ground rock. There was an increase in phosphorus in the corn plants on plats receiving phosphate. The addition of lime decreased the availability of the phosphoric acid, and a liberal supply of organic matter appeared to increase it. Tests at the Kentucky station showed a wide difference in the behavior of phosphates in different kinds of soils, with and without lime.

In a comparison extending over nine years, the Missouri station found acid phosphate, steamed bone meal, and raw rock phosphate, applied in equal money values with manure, to give approximately equal crop increases.

Potash.—The Illinois station found that both buckwheat and spring wheat showed a marked ability to utilize potash-bearing minerals. Shale and leucite produced considerably more dry matter than orthoclase or raw alunite. At the Ohio station, in comparative tests of ammonium sulphate, sodium nitrate, calcium sulphate, and monocalcium phosphate, ammonium sulphate was most active in making soil potash soluble. Ignition increased the solubility of the potash. Extraction with one-hundredth normal nitric acid showed availability agreeing well with that indicated by field and pot experiments. In sand cultures with buckwheat at the Pennsylvania station, adding calcium carbonate and sulphate to orthoclase increased the amount of potash in the plant tissue. Sodium chlorid increased the dry weight of plants, but seemed to reduce the available potash. Sodium sulphate did not affect the availability of potash or the dry weight of plants. The Texas station found a relation between the potash removed by crops and that dissolved from soil minerals by fifth-normal nitric acid.

Manure.—Applications of manure at the rate of 8 tons per acre materially increased the amount of soluble potash in the soil in experiments at the Iowa station. Tests by the New York State station showed acid phosphate to be a good preservative of manure, whereas gypsum seemed to have no good effect and under certain conditions was harmful. Dried peat gave fairly good results but may be too expensive. Straw added to rotted manure gave poor results, the manure losing nitrogen rapidly, and no preservative action was noted. The mixture had a depressing effect on the crop, as if there were toxic action. Some indications were found of a toxic agent in the straw extracts when applied to wheat and barley seedlings.

FIELD CROPS

Wheat.—In a study of the chromosome number of Triticum species, the Maine station found einkorn or *Triticum monococcum* to have seven pairs of chomosomes, and the emmer group, including *T. durum*, *T. turgidum*, *T. polonicum*, and *T. dicoccum*, 14 haploid chromosomes, whereas the bread wheats, including *T. vulgare*, *T. compactum*, and *T. spelta*, have 21. Species crosses were fertile if the chromosome numbers were the same, but partially sterile if different. In crosses between species with 14 chromosomes and those with 21, 14 pairs of chromosomes underwent a regular reduction, while 7 were assorted at random. Environmental studies with wheat at the New York Cornell station showed that within pure lines there was no particular genetic change, whether this crop was grown in poor or in rich soil. Inheritance studies at the Washington station indicated that the horny endosperm of Turkey wheat is transmitted as a unit character, the segregation taking place in the heads of the F_1 plants.

Investigations at the Colorado station showed that cold water in early irrigation retarded the growth of grains and that irrigation after blossoming lowered the yield. The highest yield was obtained when irrigation was applied at the time of jointing. Late irrigations gave better filling out of the grain and better quality. With corn the best results were obtained by irrigating at the beginning of tasseling, but early irrigation was found to be necessary to start the crop off well.

Studies on the sterility of small grains at the Arizona station showed that varieties having the most tillers had the greatest number of sterile spikelets. It was also noted that the heavier and longer the straw and the heavier the spike, the fewer the sterile spikelets. Anything that stunted the plant increased sterility.

Milling tests at the North Dakota station with hard red spring wheat varieties showed, with one exception, no significant difference in loaf volume. The new rust-resistant variety, Kota, was a little higher than Marquis in loaf volume, water absorption, and gluten content, but a little lower in texture and color. Durum varieties were distinctly inferior to hard red spring varieties in breadmaking quality, especially loaf volume and texture, The hard red spring wheats showed practically no change in baking quality after storing, but the durum wheats showed first a decrease in loaf volume, then a large increase, finally giving a volume larger than in the initial baking. Durum wheat doughs from stored samples lost the stickiness characteristic of durum flour. In milling tests at the Kansas station the best results as to keeping quality and grinding were obtained with 15.5 per cent moisture and a temperature of 20° to 25° C.

The Montana station found that frost injury lessened the amount of proteins and increased the amino compounds. Aging the wheat or flour after frosting reduced the amino compounds and greatly improved the quality of the loaf. It was concluded that the value of frosted wheat is almost always higher than the grades given it in the grain trade.

Tests at the Idaho station showed that available nitrogen in the soil is an important factor in the formation of protein in wheat throughout the entire cycle of plant growth, and that it also has an effect on the yield. Climatic factors, especially moisture, greatly influence the protein content when sufficient nitrogen is available.

Selections of Federation and Hard Federation from Australian wheat varieties outyielded early Baart more than 20 per cent at the Oregon station. Pure line selections of wheat were found that are immune to both species of stinking smut, although thus far the immune strains are not equal in yield to the leading commercial strains. Hard Federation spring wheat outyielded Marquis at the Montana station for two years, 7 and 8 bushels respectively. It has excellent milling and baking qualities. The station has developed a selection of Kharkof under the name of Montana 36, which in a 6-year trial has yielded 2.4 bushels per acre more than any other variety with which it was compared. It is being extensively grown.

Oats.—The Iowa station developed and distributed a new variety of oats, the "Iogren," from selections of Green Russian, which it outyields by 7.6 bushels per acre. The grain is a bright golden yellow, but it is considerably later than Iowar. The Kansas station secured selections of Burt oats that remained resistant to smut for four generations. The relation between amount of smut and yield was not always found to be a direct one. Other factors, such as early maturity and plant kernel characters, were in some cases more potent than smut in determining yield. A strain of oats was produced by the Wisconsin station, named the "White Cross Oat," which has white kernels much larger and heavier than those of other varieties. In 1922 it yielded 62.8 bushels per acre. Lodging appeared to be dependent largely upon the variety used as seed; but the rate of seeding

also exerted considerable influence, lighter seedings showing the least lodging.

Barley.—Crosses at the Kansas station between Nepal, which is a white, hooded hull-less barley, and Gatami, a black-bearded hulled variety, proved to be early, did not shatter so readily as Gatami and gave a higher yield than Nepal. The Minnesota station found no cumulative effect in continuous selection of barley in pure lines for earliness or yield. An improved beardless barley was developed at the Tennessee station. At the Utah station it was found that barley, like other small grains, requires not more than 15 to 17 acre-inches of water, and that water should first be applied when the plants have five or six leaves.

Corn.—Inheritance of chlorophyll color in corn apparently involves a linkage between chlorophyll and anthocyanin and between chlorophyll factors and some endosperm characters, according to conclusions reached at the Wisconsin station. Decreased vigor following inbreeding of sweet corn appeared, in studies at the Maine station, to be due to inherited characters and not to consanguinity or inbreeding per se.

Diseased seed corn produced weak seedlings, which were very susceptible to the cold weather in early spring plantings, in experiments at the Illinois station. The ear characters that proved most significant as an index of diseased condition and low yielding ability were shredded shanks, starchy kernels, brown shanks, or shanks with brown bundles. Soil enrichment did not overcome the handicap of diseased seed. It was found possible, at the Kansas station, to fix resistance to smut by inbreeding for three or four years. Strains resistant in Kansas proved to be even more resistant in Connecticut, and resistant varieties from the latter State showed from 30 to 40 per cent of infection in Kansas. Strains resistant in Kansas were still more so in Indiana. Self-fertilization as it occurs ordinarily in the field does not seem to exceed 1 per cent, according to observations by the Nebraska station. The continuous natural segregation and recombination of the elemental hybridizing characters, together with the natural element of survival of the fittest, accentuated by man's repeated selection of well-developed ears for seed, seem to account in a large measure for the inherently high productivity of field corn as now grown. In a four-year test of F_1 hybrids between pure lines, the average yield surpasses the original corn 17.2 per cent, while the most productive hybrid excelled the original by 30 per cent. Pollinating a prolific stalk with pollen from barren stalks gave an inherited barrenness in the first generation of about a 1:3 ratio in experiments at the South Carolina station. If the barren stalks were detasseled and seeds selected from prolific stalks, barrenness was eliminated. A double-crossed Burr-Leaming hybrid developed at the Connecticut State station outyielded all other station varieties of corn. Its outstanding qualities are uniformity in yield and upright stand. It requires from 120 to 130 days to mature.

Attempts at the Louisiana station to establish a pure yellow descendant by crossing yellow strains of Calhoun Red Cob and Stewart's Yellow Dent corn resulted in the establishment of the yellow, apparently as a pure character. Studies at the Virginia station showed that within a variety of corn early maturity appears to be correlated with high yield, but the controlling factor in both yield and earliness

seems to be the food supply. At the Wisconsin station selections of Golden Glow made by ice-box germination tests developed a strain of corn that germinated and developed during the cool weather of spring or early summer. There is great demand for such a strain both in the Northern States and in Canada. In order to maintain this cold-resistant character the strain must be grown in the North. This station also found that the use of fertilizers in the hill may increase the salt concentration of the sap sufficiently to enable it to withstand a lower temperature than unfertilized corn.

Sorghums.—Two distinct varieties in the character of the stalk of sorghum were secured at the Kansas station in a cross between Red Amber cane and feterita, one being juicy and one pithy, the latter proving to be entirely smut-free. The average yield of the juicy stalked plants was 7.18 tons per acre of fodder, with a grain yield of 57.64 bushels, and of the pithy stalked plants 6.31 tons of fodder and 62.48 bushels of grain. Results obtained with this cross showed that the white palatable seed, which will thresh free from the glume, and the smut resistance of feterita can be combined with the juicy stalk of Red Amber sorghum. It was found that many of the sorghums, especially milo, feterita, darso, and Freed sorghum, are very resistant to kernel smut. The Texas station developed a strain of dwarf feterita by pure line selection that is about a week earlier than any other known variety and possesses unusual drought-resistant qualities.

Forage crops.—Alfalfa was practically killed in experiments at the Kansas station when it was cut in the bud stage; when cut in the one-tenth bloom stage much grass came in; that cut in the full bloom and seed stages remained in excellent condition. From the feeding standpoint the earlier cut alfalfa was the better, and the station therefore recommends cutting in the one-tenth to one-fourth bloom stage. Experiments at the Wisconsin station showed that for the Northern States two cuttings only, at or very near the full-bloom stage, not only yielded more hay but kept the stand in a more vigorous condition. The weakening effects of early cutting were shown not only in a lower vigor but also in the crop being more susceptible to winter injury. Late fall cutting is therefore thought to be a dangerous practice as it greatly increases the liability of winter killing and reduces the vigor of the following season's growth. New seedings of alfalfa were much hardier than old stands. In experiments on the value of sulphur for alfalfa, the Oregon station found that an application of 100 pounds per acre seemed to be sufficient for about four years. The amount of sulphur received in rainfall was found to be only 4 or 5 pounds a year, whereas 40 pounds were lost by percolation.

In a study of legumes as soil builders at the South Carolina station, corn following corn with velvet beans yielded 42 bushels per acre as compared with 15 bushels on an adjoining plat of corn following cotton. With a cover crop of rye and vetch sown in cotton middles in October and turned under in May, more nitrogen was supplied to a corn crop following than it could utilize, as shown by the fact that there was no response to an application of nitrate of soda on part of the field.

Bacteria occurring on the roots of 10 species of legumes were found by the North Dakota station to be still in a very vigorous condition

after 10 months' drying in the laboratory. The Washington station found that on exposure of inoculated seed to sunlight a very high percentage of bacteria is killed during the first few days but that an appreciable number was found to be alive on the seed even after four months' exposure to sunlight. Of 60 soils of the State examined by the Colorado station for nodule formation, 70 per cent showed a natural inoculation for alfalfa.

One of the most successful ways of growing Hubam sweet clover, according to experiments by the Iowa station, is to seed it with small grain in the spring, thus producing a crop of seed the same year before frost. This crop gave best results as a green manure crop following small grain. The Louisiana station found the large yellow sweet clover *Melilotus officinalis* to be an annual in the southern part of the State but a biennial in the northern part. A yield of 31,272 pounds per acre of green material was secured, containing 104 pounds of nitrogen exclusive of that in the roots. Turning under the crop increased the yield of the following crop of sugar cane from 3 to 10 tons per acre. Annual white sweet clover yielded the same amount of hay in one cutting as biennial yellow and more than biennial white. The Montana station found that sweet clover will carry fully twice as many head of livestock per acre as any other crop now being used.

The Washington station found that with moderate rainfall biennial sweet clover stayed green late in the fall the first year and made abundant growth early in the spring of the second year; so that, if two fields were maintained, one seeded each year, pasture hay was available throughout almost the entire season. The North Dakota station found that unless properly managed sweet clover may become a rather pestiferous weed when grown in regular rotation, and that it is safest to grow it in short rotations such as a three-year one of grain, sweet clover, and a cultivated crop. The principal control measure for killing out volunteer sweet clover is late spring plowing. A sweet clover pasture showed a carrying capacity of 28 sheep per acre for a period of four months; and, except for a shortage of water for about two weeks, the pasture carried four cows per acre.

Vetch was found by the Oregon station to withstand the winter best when planted moderately early in the fall. Spring planting was not satisfactory. Best results as a seed crop followed seeding at the rate of 60 to 80 pounds per acre. It was found to fit in well in many rotations. Pollination studies showed that the varieties are largely self-sterile. Trial for a number of years proved Hungarian vetch to be of great value, being suited to wet, unfavorable conditions. It was found to yield more hay, silage, and seed than other vetches, to shatter seed less readily, to be more resistant to aphids and a good bee plant.

The sunflower crop was found by the Maryland station to draw about as heavily as other crops upon the nitrogen of the soil, less heavily than grain upon the phosphorus, and more heavily than other crops upon the potash. Owing to its heavy growth it exhausts unduly the plant food of the soil, and should therefore be grown in rotation with other crops. The North Dakota station found that the dry matter reached a maximum in sunflowers during the first week in September, when the plants are about 80 per cent headed out. The Wisconsin station showed that when sunflowers were as close together as 6 inches in the row there was a pronounced drying up of the lower

leaves before time for harvesting. Spacing of at least 8 to 12 inches is therefore recommended. The relative proportion of leaves increased as the planting spaces increased up to 12 inches, after which no further gains were obtained. Results of tests at the Wyoming station indicated that sunflowers should be planted several weeks earlier than has been the practice. The plant was found to be able to stand light spring frost and can therefore be planted much earlier than corn. Compared on an acre-yield basis, sunflowers were superior to corn. In experiments at the Oregon station, oats and vetch yielded 16 tons per acre, sunflowers 14.7 tons, and corn 8 tons. Silage made from the sunflowers was lacking in palatability. Oat and vetch silage was richest in protein and lowest in labor cost.

At the Georgia station sweet potato vines made a silage of a peculiarly pleasant odor, which was readily eaten by stock. Japanese cane made a silage as good as corn silage, but Napier grass did not make a silage of good quality. Cotton stalks made a silage which kept well but the stock left about half of it in the form of coarse woody material.

The Kansas station found that on pasture which had been burned over each year for four years there was an increase of 21 per cent in grass, as compared with an increase of 7 per cent on unburned pasture. Burning caused a change in the type of vegetation, weeds showing a tendency to decrease on the burned area and to slightly increase on the unburned. The South Carolina station succeeded in seeding cut-over land to pasture with carpet grass and Lespedeza. Some preparation by disking, and small applications of nitrate of soda and acid phosphate, hastened the development of pastures on these poor lands very materially. At the Nebraska station, pasture that was not manured carried 8 sheep per acre on a 102-day test, while manured pasture carried 16 sheep per acre. The fertilizer tests on grass plats at the Pennsylvania station showed, after a number of years, that mixtures high in nitrogen favored the grasses which crowded out the clovers; whereas on plats receiving little nitrogen the clovers were relatively abundant. Complete fertilizers with a high percentage of nitrogen gave the highest average yields of hay.

Of the cultivated grasses and clovers tested at the Nevada station for the improvement of wild hay lands, the only one giving promise of value was the common biennial form of sweet clover. This was found to root well under somewhat unfavorable moisture conditions and did not drown out readily under excessive flooding of the soil. It also proved to be rather more resistant to alkali than other plants and grasses tested.

The Florida station found Bahia grass (*Paspalum notatum*) to be the most promising pasture grass of recent introduction. Warm weather is essential for best germination of the seed, which is poor when it is not grazed or mowed. It shows a wide range of soil adaptation. Subterranean clover (*Trifolium subterraneum*), introduced from Australia, was tested with good results on flatwoods soil as a winter annual.

Potatoes and root crops.—In a comparison at the Nebraska station of potatoes grown on dry land and under irrigation, it was found that taking the yield from dry land seed as 100 per cent, seed from plants irrigated one year yielded 85 to 90 per cent; irrigated two years, 60 to 75 per cent; three years, 40 to 65 per cent; and four

years generally less than 40 per cent. A few irrigated strains showed a tendency to maintain their vigor fairly well under irrigation. Potatoes grown continuously on the same land became so scabby as to be unmarketable. In a six-year rotation they were generally free from scab, while in a four-year rotation the amount of scab was considerably geater. Hill selection at the Utah station increased the acre yield of potatoes from 60 to 90 per cent. Selected stock grew more quickly, gave better stands, and produced higher yields of better quality, giving smoother and more uniform tubers and fewer culls.

In a test of size of seed piece at the Oregon station, using 20 bushels of seed potatoes per acre, cut into 1, 2, and 3 ounce pieces, larger yields were secured from the smaller pieces planted closely, 1½-ounce pieces being the most economical size. One-and-one-half-ounce whole-blossom end pieces yielded more marketable potatoes than similar-sized split-blossom end pieces. Planting 5½ inches deep gave higher yields than planting 3 inches deep. Treatment after cutting seed potatoes gave a reduced yield as compared with treatment before cutting in experiments at the North Dakota station. Potatoes soaked in water showed injury after a comparatively short time, dependent upon the temperature of the water. In spacing tests at the Wyoming station, including hills from 6 to 36 inches apart, the 6-inch spacing gave the highest yield of marketable tubers (305 bushels per acre), 36-inch giving only 129 bushels. Hills next to missing hills did not give definitely larger yields than normal hills. Planting one-fourth of medium-sized tubers gave the largest yield per acre (246 bushels) and one-sixth of large-sized tubers gave the lowest yield (130 bushels per acre). Large plants gave the largest yield of tubers per hill and also the largest tubers. Four stems per hill gave the greatest yield of marketable tubers per hill, but the hills with single stems produced the largest tubers.

At the Kentucky station the loss in storage at 60° to 85° F. of sweet potatoes the vines of which had been cut before frost was 4 per cent. When the vines were cut immediately after a freeze no loss occurred; when cut five days after a freeze the loss was 88 per cent. Potatoes wrapped in paper sustained a loss of 20 per cent, compared with a loss of 12 per cent in case of unwrapped potatoes. Tests at the Mississippi station showed that the lowest temperature sweet potatoes can safely stand after being cured is 28° F.

The Colorado station found that when soil nitrates reached 400 pounds per acre there was a decrease in sugar content and decline in quality of the sugar beet, as well as an increase in susceptibility to disease. The specific effect of excessive nitrates appeared to be an increase in the noncrystallizable sugars. In tests at the Utah station, beets 1 foot apart in the row gave a higher yield than any other distance of planting; and one or two small irrigations in alternate furrows early in the season, followed by irrigation in every furrow for the balance of the year, gave best results.

Cotton.—The name "Louisiana No. 1" has been given to a long-staple cotton developed by the Louisiana station from a cross between Dixie and Louisiana Hybrid No. 143. This has a staple of 1.5 inches, with a good percentage of lint. The yield of cotton following corn and soy beans planted together was approximately 100 per cent greater than that of cotton following corn alone.

Breeding and selecting for high and low oil and protein strains at the Arkansas station resulted in strains that show a difference of 4 to 5 per cent from the average, or about 9 per cent between extremes. The highest percentage of oil and protein obtained is about 30, but it is believed that these high percentages will quickly go down without constant selection. Results obtained at the South Carolina station indicate that the oil content is largely dependent on other factors than heredity. A difference of 10 per cent in oil was noted in the same variety grown in Arkansas and Tennessee. All varieties showed a higher oil content in Florida than in Tennessee. The oil content of the same variety grown on different plats often varied as much as those of different varieties. No decided correlation was found between the kind and amount of fertilizer applied and the oil content of the seed. The Texas station reports that earliness is found to be correlated to the putting out of the first lobed, mature-shaped leaves, which is helpful in the roguing of this characteristic.

Tobacco.--The Kentucky station found that in White Burley tobacco the nitrogen content of wrappers was different from that of fillers and smokers, as was also the nicotin content. Although nicotin content of the best of a given grade was usually much larger than that of the common, there was little difference in the total nitrogen content, suggesting that the common types may have nitrogen in some form which goes to make the tobacco inferior. The White Burley tobacco contained much more nitrogen as nitrate and less nicotin than the dark tobaccos. The ash of White Burley was found to contain more phosphorus, potassium, and calcium, and less silicon and magnesium, than that of dark tobacco. Six strains of White Burley tobacco developed by the station proved to be earlier, more uniform in growth and type, and resistant to root rot when grown in diseased soil, with as good or better quality than that commonly grown. Two selections of Vimont Kelley White Burley were found which were practically immune to root rot. The Ohio station reported that two improved varieties, Montgomery seed leaf and Tall Zimmer, were distributed and raised by pratical growers with encouraging results.

HORTICULTURE

Fruits.—Yellow Newtown apples picked late in October developed "fruit pit" and later broke down on storage in experiments at the Oregon station. Fruit picked early in October held up well, but did not attain such large size. October 15 appeared to be the most practical time to pick this variety in Oregon. Esopus Spitzenburg picked October 6 was of better keeping quality and flavor than those picked on October 18. Anjou pears attained best size and quality when picked as late as October 1 to 8. On an average this fruit increased from $\frac{10}{16}$ to $\frac{13}{16}$ inch in circumference during the last month of growth, and shrinkage in storage was less in late picked than in early picked fruit. The coloring was also better.

The effect of aeration in storage by means of electrical fans varied with the different varieties of apples in experiments at the Iowa station. No soft scald occurred on Jonathans where they were well aerated, but aeration was not so efficient in preventing scald on Grimes Golden. Wrapped apples scalded very little. A comparison of com-

mon paper, waxed paper, tinfoil, and oiled wraps showed that scald was practically controlled in all cases where oiled wraps were used but not in the other cases. Grimes Golden stored at optimum maturity showed very little scald.

Many varieties of apples mature before they are well colored, according to the Washington station. Apparently such factors as color of fruit, color of seeds, size of fruit, or ease with which it breaks from the stem, or a combination of these can not be used as a safe guide in determining when varieties should be picked.

For practical purposes all commercial apple varieties are self-sterile, but most varieties are interfertile, according to results reported by the Maine station. Bumble bees were found to be an important factor in effecting cross pollination. There was high correlation between size of nursery trees and ultimate size after six years in the orchard. The great variability found in a study of 881 Ben Davis trees was attributed primarily to differences in soil, variable root stocks, and differences in individuals of a clonal variety due to bud nutrition. The first two factors were influential in causing differences in yield.

In a test of a large collection of all known species and varieties of pears of this and other countries, the Oregon station found a very small percentage resistant to blight, but very promising as blight-resistant stock on which to graft commercial varieties. Seedlings of even the common varieties varied greatly in resistance, only a small percentage proving immune. It was found that the time of picking did not greatly influence the keeping quality, except that fruit picked very early should be partly ripened under more humid conditions and for a longer period than those picked later. Fruit kept three months longer when given a delayed storage of 10 to 15 days at ordinary temperature than when given 12 to 15 days of refrigerator car temperature at a humidity 60 to 70 per cent.

The Oregon station found that Bing, Napoleon (*Royal Anne*), and Lambert cherries are intersterile, and recommends planting one Black Tartarian to every 20 trees of these varieties.

The California station found that since sour stock is apt to vary greatly, only selected strains should be used for propagation of citrus fruits. The use of arsenical sprays on citrus trees was found to reduce the acid content of the fruit and make it insipid. The internal decline of lemons was found to be a physiological trouble, related to the breakdown of fruit as it nears maturity. No organism was found in connection with the trouble. The Florida station found in a test of fertilizers that citrus trees receiving no potash had more sugar and less acid than those receiving potash, there being also an increase in invert sugar in the no-potash trees. The no-potash trees were, however, smaller and produced smaller fruit than those receiving potash. The Arizona station showed that the use of summer cover crops was a means of preventing premature shedding of leaves and that clean cultivation during the winter lessened winter injury to the citrus trees.

In experiments on the drying of prunes the Oregon station found that temperatures in the drier as high as 180° F., with a high humidity, were injurious. The best quality was obtained at a temperature of 150°, a humidity of 15 to 20 per cent in the drier, and the movement of air through the drier at the rate of 75 feet per minute.

In a study of the viability of grape pollen the North Carolina station found that pollen of the variety tested kept its viability for 15 days, and it was concluded that with proper drying and packing it might be sent long distances and still be effective. The South Carolina station obtained the best results by letting two canes come up from the ground, training one to the first wire and the other to the second wire of the trellis, thus giving two terminals and allowing more light on the lower arms.

Studies of strawberries at the Missouri station indicated that nutritive conditions in the soil in the spring, immediately preceding and during the fruiting season, are of less importance in influencing yield than are the conditions immediately preceding and during the period of fruit-bud formation. The Oregon station found that heavy applications of nitrogen and comparatively low applications of potash produced the largest yields. Where much potash was used, small, seedy berries resulted; but with excessive nitrogen the berries although large were inclined to be soft, especially during a short hot ripening season.

The factors directly concerned in the jellying of fruit are, according to the Delaware station, the pectins, sugars, and acids. Jellying depends more on the H-ion concentration than on the total strength of the acid. The lowest jellying point was found to be at approximately pH 3.4 and the optimum point at pH 3.1. At pH 4 and above it was impossible to make a jelly. By determining the H-ion concentration of the juice and its pectin content, the material to be added to make it jelly is easily calculated. Most of the fruit juices examined had a concentration of about pH 3.

Nuts.—Pollination of the filbert was found by the Oregon station to take place in January or February, but the act of fertilization did not occur until June. All varieties observed were self-sterile. In investigations on walnut die-back at the California station it was found that trees in orchards in which the soil moisture was reduced to the hygroscopic point during the ripening period and continued to the middle of the dormant period escaped injury. If rains came they suffered from die-back.

Vegetables.—Home-grown bean seed, acclimated through several years of growing and selection, produced mature string beans two weeks earlier than seed from the same variety obtained from various seed houses in experiments at the Montana station.

An increase in yield of Lima beans was obtained at the Illinois station by inoculating with pure cultures of the nodule organism of cowpeas.

The failure of lettuce to head was corrected in experiments at the Kentucky station by drenching the soil and manure with formaldehyde.

The best germination of lettuce seed was secured at the Minnesota station by soaking the seed for six hours and then exposing to indirect sunlight at a constant temperature of about 73° F.

Two wilt-resistant varieties of tomatoes, originated by the Louisiana station, the Louisiana Pink and Louisiana Red, are widely distributed over the State and are giving generally good results.

The maturity of tomatoes was hastened in tests at the New Hampshire station by the application of acid phosphate. Manure increased the yield but did not hasten maturity. Potash had no appreciable effect upon maturity.

The North Dakota station found that low temperatures were unfavorable for the winter storage of squashes.

Ornamentals.—The tamarisk, in trials at the Arizona station, withstood a temperature of 12° F., but should have no irrigation after September 1. It thrives in alkali soil, and the wood is close-grained and hard. The species *Tamarix articulata* has proved very valuable for windbreaks for citrus orchards, as it makes a very rapid growth. The pistachio tree was found to be tolerant of alkali and exteme heat and is not injured by a temperature as low as 6° F.

Pink-flowered hydrangeas became blue when the H-ion concentration was below 6.4 in tests at the New Jersey stations.

A very promising cross of the American Beauty rose with native species, which is very hardy, with about 50 well-developed petals, was secured by the South Dakota station.

Orchard management.—The New Hampshire station found that if an orchard is thoroughly cultivated, the use of a complete artificial fertilizer does not give sufficient increase in yield the first 10 years to be profitable under New Hampshire conditions. The chief deficiency in a sod orchard was found to be nitrate nitrogen, which can be efficiently supplied as a chemical fertilizer, thus making it possible to extend the orchard industry to lands which are not suitable for cultivation.

Applications of nitrogen, as nitrate of soda or in the form of a cowpea cover crop, were very profitable with apples in experiments at the Illinois station. Mulching with grass and legumes grown between the trees was more profitable than clean cultivation. With peaches, clean cultivation and heavy fertilizing with nitrogen and potash gave the best results. Cowpeas proved very detrimental to the growth of the trees and the yield of fruit unless fertilized with potash.

Injecting nitrates into the roots of trees gave quick response at the Ohio station, and by inarching small trees on larger ones it was possible to feed one tree through the roots of another.

Nitrates increased production 300 per cent in neglected sod orchards the first year of application in experiments at the Indiana station. Tests extending over 11 years showed that apple trees under cultivation with cover crops and a heavy straw mulch produced three to four times as much fruit as trees in sod, but when nitrate of soda was applied there was a marked increase in tree growth on the grass plats over the cultivated plats. The root system was largest and extended to a greater depth in the tilled soil than in soil under straw mulch or grass. Trees in sod were seriously dwarfed in both roots and tops.

In an apple orchard in timothy sod, at the New York Cornell station, nitrate of soda up to 900 pounds per acre had very little effect after a few months, but in a cultivated orchard it had a marked effect which increased in proportion to the amount applied. Like results were obtained in cherry and plum orchards.

Continuous clean cultivation of irrigated apple orchards was found at the Washington station to exhaust the organic matter and t

develop a hard, compact subsoil immediately below the depth of the plowed layer, as well as a very poor physical condition of the surface soil. The compact condition interfered with the penetration of moisture and the efficient use of irrigation water. The temperature of the soil under alfalfa was found to be 64° F., while in bare fallow it was 96°. The soil temperature during July and August was 8° to 10° lower under permanent alfalfa than under bare fallow. Similar studies at the Arizona station showed that soil under a cover crop was 6° to 8° cooler than cultivated soil. The latter showed 40 per cent less evaporation and a higher humidity. The temperature of the soil under a cover crop was 2° or 3° higher, and its humidity in summer was 10 to 12 per cent higher than that of the atmosphere. The Montana station obtained the best results by clean cultivation of young apple orchards or by intercropping with a cultivated crop for a few years and then putting in a clover cover crop. The inadvisability of clean cultivation year after year was demonstrated.

Hardiness and winter injury.—Environmental conditions during freezing, such as length of exposure to low temperature, the rate of temperature fall within limits which are possible under field conditions, and the rate of thawing after freezing are, according to the New Hampshire station, of relatively small importance in case of apples, the amount of injury depending most largely upon the degree of temperature to which the roots are subjected. Roots exposed to a minimum temperature of 45° F. for one-half hour were 27 per cent injured; exposed for 4 hours, 31.5 per cent; and for 18 hours, 43.5 per cent. When the drop in temperature was sudden, there was more injury than when it was slow. Injury was greater in moist than in dry sand. The part of the root just inside the cambium layer was found to be most susceptible to winter injury, but growth was not seriously affected unless the outer (phloem) cells were also injured.

At the Arkansas station apple trees in which a good growth in the fall was maintained by the application of nitrates escaped much of the frost injury in the spring. The pollen was not hurt by frost injury sufficiently to destroy the pistil and ovary. There was much difference in the viability of pollen from different varieties.

The Missouri station found hardiness to be dependent upon the water-retaining capacity of the plant cells, an increase in which enables the cells to retain a larger proportion of their moisture content in an unfrozen condition. A relation was found to exist between water-soluble pentosans and the water-holding capacity.

The buds of the hardy varieties of peaches were found by the Maryland station to contain less water than tender varieties. The moisture content was found to increase early in the spring; but this increase was dependent upon the temperature, no increase taking place below 43° F. The buds appeared to get their moisture from the roots rather than from the twigs.

Winter desiccation of fruit trees is, according to the Washington station, serious at times under certain semiarid conditions; and as it occurs only where the humus content of the soil is low and the nitrogen quickly exhausted, it is believed that the latter element is the limiting factor in its occurrence. It is characterized by rosette leaf formation and chlorosis in the new growth, chemical analysis showing this abnormal growth to be high in ash and with abnormal per-

centages of nitrogen. When infected twigs were grafted into normal wood they outgrew these conditions. It was found that growing leguminous cover crops in the orchard tended to correct the trouble.

Pruning.—The necessity of regulating pruning practices to the varied habits of the tree and the hazardous nature of most summer pruning practices were emphasized in studies at the Oregon station. No form of summer pruning was found as favorable to tree growth and spur development as winter pruning.

The amount of pruning of mother shoots had little influence upon the total amount of new laterals produced in the following season in experiments at the California station. Fruit spurs were commonly more abundant upon unpruned mother shoots than on those pruned the previous winter. A new method of pruning young olive trees was worked out, which hastens the development and shortens the time of coming into bearing.

Rest period.—The Missouri station found the rest period to begin when there was a maximum H-ion concentration of the sap. Phosphorus increased during the winter in the buds faster than nitrogen and H-ion concentration, and then began to drop, the phosphorus apparently neutralizing the acidity. The rest period, however, was apparently not determined by the H-ion concentration.

PLANT DISEASES

Cereal diseases.—The Minnesota station reported additional biologic strains of cereal rusts as distinguished by their reaction to different host species, making a total of 37. Progress was made in the development of strains of wheat resistant to rust. The uredospores of black rust were found to retain their viability until late in March while the first infection of barberry by sporidia from teleutospores did not appear until May, and on wheat still later.

Investigations at the Nebraska station showed that the uredospores of the stem rust of wheat remained viable for 16 weeks at 41° F. with a humidity of 50 per cent. No germination was evident when the spores were kept for two weeks at 86° F., and there was only slight germination at 77° F. No viable spores were found late in the winter or early spring under natural conditions.

The Idaho station found over 60 wild grasses to be hosts for the stripe rust of cereals. No alternate host plant was found. The summer stage overwintered in wild grasses and winter wheat in Idaho.

At the Indiana station five varieties of wheat of economic valu were found to show fairly uniform rust resistance when tested in number of localities and States, all being of the Turkey type, no well adapted to the eastern United States. The æcial stage of th rust was produced in the field. A number of strains of rust wer found, some varieties of wheat being resistant to one strain and no to another.

The Indiana station found the æcial stage of the leaf rust of bar ley on the Star-of-Bethlehem, which in some sections has escaped fro cultivation and become a weed.

The Idaho station established the fact that the temperature an moisture content of the soil have a very definite effect upon th amount of smut present in the crop at harvest. The amount

infection increases as the amount of moisture increases up to saturation. The highest infection developed at the lowest temperature.

The method of treating the seed with dry copper carbonate dust mixed with a little lime, devised by the California station, is being widely practiced. Tests at the Washington station showed that 2 ounces of copper carbonate to a bushel of seed caused no reduction in germination but rather improved it, treated seed showing a more rapid germination, a more vigorous growth, and greater freedom from winter injury than untreated seed. One-half ounce of carbonate gave nearly as good protection as 2 ounces, and 3 ounces gave slightly better results. The maximum percentage of smutted heads from treated seed was 5.41 and from untreated seed 64.4. Copper carbonate gave better protection against smut from soil contamination than formaldehyde and was equal to or better than bluestone treatment.

The Oregon station found a large amount of seed injury due to treatment with formaldehyde or copper sulphate for smut control, whereas dusting the seed thoroughly with powdered copper carbonate showed practically no injury and the results as regards smut control appeared satisfactory.

In a state-wide three-year survey, the Virginia station found that three bearded varieties of wheat—Stoner, Red Wonder, and Fulcaster—showed much greater infection with loose smut than the beardless varieties—Harvest King, Fultz, and Leap.

The Idaho station showed that low soil temperatures and a fairly high percentage of moisture in the soil are both conducive to infection with stinking smut or bunt. Most infection occurred at temperatures ranging from 9° to 12° C. (48° to 54° F.), with 22 per cent of soil moisture. Some infection occurred, however, during germination at a temperature of 25° to 28° C. (77° to 82° F.). Very little infection took place from spores which had been in the soil one month under the above conditions. Spores lost their viability in moist soils repeatedly cultivated. It was found that under Palouse conditions infection took place after the plant emerged from the soil. No dust treatment gave as good control of the disease as the standard bluestone dip treatment

At the North Dakota station in several hundred isolations from seed and seedlings of wheat, barley, and rye affected with scab, *Gibberella saubinetii* was found in every case, and in no case was *Fusarium culmorum* found. The embryo of the grain was the first part infected, the infection later extending to the endosperm. Careful cleaning and grading of the seed reduced the disease.

At the Missouri station the limiting acidity for seedling infection by *G. saubinetii* was found to be pH 5.5. This is not an unusual soil reaction, and is one to which soils could easily be adjusted.

In seed treatment for wheat blight, at the North Dakota station, good results were obtained with parachlorphenolate of mercury, commercially known as chlorophol, which apparently penetrated the seed coat and reduced the amount of infection. Infection in black-pointed grains was found to be due to a species of Helminthosporium closely resembling *H. savitum.* The embyro itself was found to be penetrated by the mycelium, and when moisture was supplied the fungus formed enlarged lesions in the primary roots before they broke through the seed coats. Spores of the fungus were frequently found

under the seed coat in these lesions. Such grains frequently failed to germinate.

The Kansas station isolated the organism from root rot or take-all of wheat and identified it as *Ophiobolus careceti* with *Wojnowicia graminis* commonly associated with it. The pathogenicity of the latter was not determined. It was apparently carried over in the stubble and probably in the soil. A rotation with cereals every four or five years seemed to offer the best control. Studies at the Indiana station showed that the disease may persist in the soil for three years. Some varieties were found that were immune to the trouble.

The Tennessee station found that the following fungi are very commonly associated with wheat seed in the order mentioned: Alternarias, Helminthosporia, and *Gibberella saubinetii*. The fungi most commonly associated with wheat roots were Helminthosporia and Fusaria.

Corn diseases.—Studies at the Indiana station showed that potash in the form of kainit tends to correct corn root rot on acid muck soils, but no benefit was derived from applications of lime or phosphate on such soils. On the other hand, the application of lime and phosphorus to an Indiana clay soil apparently affected the absorption of potash so that an accumulation of iron and aluminum compounds in the nodal tissue did not take place. The results indicate the importance of potash in the control of root rots, although this probably does not depend upon any one factor but upon the complex relation of essential nutrients in the soil solution. A definite relation was found to exist between the nodal tissue discolorations and the disintegration and the absorption of iron and aluminum compounds from the soil.

In studies of corn root rot at the Kansas station, the following organisms were found in the order of their prevalence: *Fusarium moniliforme*, *Diplodia* sp., and *Gibberella saubinetii*, the second and third being the common cause of wheat scab in Indiana and Illinois. *F. moniliforme* was present in 80 per cent of the samples examined.

The Maryland station found that seed selection for root rot reduced general infection 7 per cent, and the severest infection 40 per cent.

A survey of seed corn in the State made by the Missouri station showed a high percentage of infection. In the order of their prevalence, the associated organisms were *F. moniliforme*, an organism closely resembling that variously described as *Cephalosporium sacchari*, *Diplodia zeæ*, and *G. saubinetii*. The amount of root and stalk rot in the field was correlated with the amount of infection in the seed. Seed disinfection reduced this to a considerable extent.

The Nebraska station found that root rot is quite definitely associated with type of ear, the smooth flinty type having the least rots.

The New Jersey stations isolated four organisms associated with this disease, two of which gave positive results under inoculation.

The Ohio station found that while root rot was usually caused by *Diplodia zeæ*, it sometimes resulted from the interaction of various organisms. Its damage may be greatly reduced by the use of the rag-doll germination test.

Studies at the Iowa station showed that infection with the dry rot of corn takes place at the top of the ear and at the nodes of the stalk. The fungus does not migrate up from the roots but lodges at the base

of the leaves and feeds on the old pollen collected at these places, later attacking the shanks and butts of ears. The fungus lives over winter in the spore stage on old stubble. Practically no injury was manifest on rapidly growing corn, attack being delayed until after flowering, the greatest damage being done after growth stopped. Hot, wet weather at the time of denting was most favorable to the spread of the fungus. The injury to the seed is of great importance, many small kernels being killed outright, and in others the viability is so lowered that they produce weak plants.

The Tennessee station found *G. saubinetii*, the wheat scab fungus, to be seldom associated with corn seed, although it is common on dead cornstalks. The seed is not infrequently infected with the Fusaria of the elegans type, but most commonly, both externally and internally, with Fusaria of the moniliforme type, although these are by no means all of the same species, differing from each other in several morphologically important characters, thus representing several distinct organisms. Seed heated with hot water at 129° F. for 10 to 20 minutes was not affected either as to germination or fusarial contamination. When, however, the temperature was raised to 131° F. and higher, the fusarial contamination was greatly reduced, although the highest temperature tried, 139° F, did not completely free the seed from contamination. Germination was retarded by temperatures of 134° F. and up. Presoaking the seed in hot water (125°–130° F.) for a period of 24 hours was partially effective against fusarial contamination. Longer soakings were less effective. Corrosive sublimate treatment was very effective against surface contamination, but entirely ineffective against internal contamination. The treatment greatly reduced decaying of the primary root system of corn seedlings when the treated seed was planted in unsterilized, rich garden soil. The combined hot water and corrosive sublimate treatment was very effective.

The Delaware station found that, of the various organisms concerned in the more common corn diseases, *G. saubinetii* was most active in reducing yields, in causing root rot, and in crippling seedling roots.

Cotton diseases.—The Arkansas station reported a new blight of cotton caused by *Ascochyta gossypii*, which attacks all aboveground parts of the plant and may completely kill it. It also causes a severe boll rot. The fungus lives over winter on dead stalks in the field and infects the new crop the following spring. Rotation of crops is suggested as a remedy, but a one-year rotation was found to be insufficient to eradicate it. This station also found a wide difference in virulence in different strains of the fungus causing cotton wilt. Some wilt-resistant varieties lost their resistance in some localities. The organism is carried inside the seed, and therefore ordinary seed treatment is ineffective.

At the Arizona station it was found that cotton grown on alkali land was apparently not subject to black arm, perhaps because such plants are less succulent, the disease developing best on succulent plants.

Potato diseases.—Investigations at the Idaho station showed that calico disease of the potato is apparently transmitted not only by means of diseased tubers but also by spreading from plant to plant in the field.

Studies at the Nebraska station indicated that the leading factors in the spread of blackleg of potatoes are relatively high humidity with an optimum temperature of about 77° F. The organism remained viable with 100 per cent humidity at 77° F. At the same temperature with 90 per cent humidity, it remained viable only three hours, and at 80 per cent or less only two hours. Low temperatures and low humidity in ordinary storage cellars appeared to effectively control the disease.

At the North Dakota station it was found that a large percentage of the discoloration of the potato tubers is due to blackleg bacteria. Thirty-five per cent of discolored stem ends were infected with *Fusarium oxysporium* and 18 per cent with *Bacillus phytophthorus*, 24 per cent failing to show any fungus growth. Six per cent of the tubers were infected with both the Fusarium of wilt and the blackleg organisms.

In cage tests at the Idaho station of insect transmission of potato mosaic and leaf roll, positive results were secured only with the pink and green rose aphis (*Macrosporium solanifolii*).

In studies on Rhizoctonia at the Washington station midseason plantings (about May 20) gave the largest total yield and also the largest yield of marketable stock. Late plantings (July 1) gave the largest percentage of clean tubers. Plantings after June 1 showed a steady increase in percentage of clean tubers over earlier plantings. Seed treated with corrosive sublimate produced a higher percentage of clean tubers than untreated seed. Experiments at the Idaho station on the influence of successive dipping of seed potatoes upon the strength of corrosive sublimate solution showed that when clean, whole potatoes were treated the strength of the solution could be kept of normal strength by adding one-fourth ounce of corrosive sublimate for every 2 bushels of potatoes treated. Cut or dirty potatoes broke down the solution very rapidly, and if treated in sacks these also reduced the strength of the solution.

Experiments at the New Jersey stations showed that where potato scab had prevailed in the field the previous year, the use of from 400 to 600 pounds of sulphur on heavy soils and from 300 to 400 pounds on light soils gave the best results in control of the disease. The use of sulphur is not recommended where only a little scab has prevailed since green manures and fertilizers will make the soil sufficiently acid.

Studies at the Oregon station indicated the necessity of rotation of crops and the value of field roguing in the control of potato wilt. The disease was found to spread from plant to plant under ground during the growing season, suggesting that not only should plants be removed as soon as they show signs of wilt, but that it is safer also to remove the next plants in the row on each side.

The Nebraska station found little evidence that *Fusarium oxysporium* causes much wilt and rot of potatoes in Nebraska. *F. martii* causes a large amount of wilt. Experiments showed that infection occurs more commonly from the soil than from the seed. Discoloration of the tuber is not an absolute criterion of the presence of the fungus. The Delaware station found that *F. eumartii* causes a trouble similar to *F. oxysporium*. Positive evidence of the overwintering of *F. oxysporium* in the soil was secured, but healthy tubers planted in soil developed infection.

The Maine station continued its extensive studies on degeneration diseases of the potato, including mild mosaic, crinkle mosaic, rugose mosaic, leaf roll, streak, spindle tuber, and curly dwarf. Transmission by aphids was demonstrated for all except streak, by leaf mutilation inoculation for all except leaf roll, and by grafting for spindle tuber disease and others except leaf roll. Spread in the field by natural means was greater the larger the number of aphids present. Tests of means of control of these diseases showed roguing to be incompletely effective and fertilizer treatment to be useless. Bin and hill selection are only partly effective. Insect elimination was difficult to secure over large areas. Selection and isolation of healthy strains were effective. The "running out" of potatoes was found to be traceable to a number of diseases varying with variety and climate as to symptoms, percentage of infection, and rapidity of spread; otherwise there appears to be no such thing as "running out." Uniformly strong stock planted in isolated fields (at least 300 feet from previously planted fields) and the removal of all weak hills before plant lice appear reduced degeneration, while the omission of these precautions resulted in degeneration.

Tobacco disease.—Experiments at the Wisconsin station showed that the organism of the black root rot of tobacco can persist in the ground at least six years even in the absence of the tobacco plant as a host, but gradually decreases in virulence. The Kentucky station found soil infection with *Thielavia basicola* to be widespread, persistent, and difficult to control. Some especially desirable strains of White Burley tobacco resistant to the root rot have been developed. Soil sterilization did not give entire satisfaction at the Georgia station as a means of controlling root rot. The Wisconsin station has had several strains that seem to have marked resistance to the disease The Connecticut State station secured the asco stage of one strain of tobacco Thielavia from the violet and also found it on sweet and garden peas.

Studies on tobacco wildfire at the Connecticut State station showed that the disease can carry over on unsweated tobacco leaves, but is not carried over in the field to any extent. Driving rains help to spread the disease. The seed is not thought to be much of a factor in transmission. There does not seem to be much hope of securing immunity. Broadleaf tobacco suffers especially from the disease on account of its habit of growth. It is not bad on Cuban tobacco grown under cover. The station has developed promising methods of control. At the Massachusetts station it was found that success in controlling wildfire does not always result from sterilizing the seed bed with corrosive sublimate. The organism will live over on tobacco leaves, suggesting that it might be spread by the dust from such leaves. No evidence was found that insects spread the disease. Studies at the Virginia station of the control of angular leaf spot (blackfire) and wildfire showed seed selection and disinfection and plant bed and field sanitation to be practical measures which greatly reduce losses.

Other field crop diseases.—The Utah station studied what appeared to be an undescribed root rot of the sugar beet which appears to be especially favored by insufficient irrigation and is characterized by a fungus attack on the beet below the soil line, working upward in the

tissues and eventually destroying the crown. Examination of the leaves showed what appeared to be typical mycelia of the sterile or Rhizoctonia stage of *Corticum vagum*. The disease was reproduced by inoculation experiments into healthy beets.

Investigations at the Louisiana station indicated the possibility of selecting strains of sugar cane more or less immune or tolerant to mosaic, and the Porto Rico station found that the introduction of immune varieties furnishes an effective means of control of this menace to the sugar industry.

Studies at the Montana station indicated that sunflower wilt is probably due to a species of Sclerotinia. Seven strains have been isolated that are culturally identical or nearly so. The disease usually makes its appearance when the plants are 4 to 6 feet high, attacking roots and crowns, and the plants wilt and die. Losses range from 10 to 60 per cent of the sunflowers in the field. The fungus appears to spread through the ground rapidly. In one instance it was found to attack a patch of Canada thistles, and there is some evidence that wild and cultivated lettuce are possible hosts. The organism was found wintering over on all sunflower stalks. The perfect stage was not found. It is believed that a rotation of sunflowers with grasses and grains would lessen the loss. A downy mildew of sunflowers caused by *Peronospora halstedii* was also found.

Tomato diseases.—Studies on tomato blight at the Maryland station showed that the organism (*Septoria lycopersici*) lives over winter in the dead stems of the tomato and also on the horse nettle, Jimson weed, and potato. The perfect stage was not found. Considerable success was attained in developing an early resistant tomato. At the Washington station some evidence was obtained indicating that the disease may be due to the joint attack of a Rhizoctonia and a Fusarium. The Rhizoctonia on the tomato was found to be the same species as that occurring on the potato. The New Mexico station found that the disease can be materially reduced if medium to heavy soils are used instead of light soils.

Examination at the Washington station of a large number of apparently healthy plants showed a very large percentage of these to have mycelium of Rhizoctonia in abundance and over 50 per cent to have sclerotial development on the roots, proving that the tomato may be infected with this fungus and not display symptoms of blight.

In a study of tomato mosaic at the Indiana station much evidence was obtained of the overwintering of the disease on the horse nettle and certain ground cherries. Eradicating these weeds from plant beds and fields resulted in a marked control of the disease.

The Arkansas station found tomato wilt to be a seed-borne disease, probably both inside and outside of the seed. Some progress was made in developing wilt-resistant varieties.

The West Virginia station reported a new disease of tomatoes, a rot apparently due to Pythiacystis, which also causes the brown rot of lemons.

Other vegetable diseases.—At the New Hampshire station dusting with Bordeaux mixture gave satisfactory control of bean anthracnose, especially if sugar was added, which reduced the amount of scorching. This treatment reduced the disease to 0.3 per cent.

Studies of an apparently unrecorded disease of Lima beans at the Virginia station, attacking the beans in the pod to a serious extent in some sections, showed the causal organism to be a yeast, a species of Nematospora.

The Massachusetts station isolated a species of Macrosporium from carrot blight that gave 100 per cent infection by inoculation. The disease affects the seed-bed plants, as well as those in the field. Bordeaux mixture gave fair control, depending upon weather conditions.

The Michigan station found celery yellows to be seed-borne, some varieties being resistant to it.

Cucumber mosaic was found by the Wisconsin station to be carried over winter on the pokeweed, milkweed, and wild cucumber, and was transmitted to pigweed and the cultivated ground cherry.

The New Jersey stations found that seeds from fruit affected with eggplant wilt were free from it. Infection may occur in the seed bed, transplant bed, or field.

The Arizona station isolated a bacterium from the bacterial rot of lettuce that will produce the rot when inoculated into healthy plants. The Kansas station found that a Botrytis disease causing flower and foliage rot of greenhouse geraniums produced a gray mold on lettuce, causing a slimy rot. The Kentucky station found that the organism causing root rot and tipburn of lettuce is seed-borne and may be prevalent in garden soils and refuse, but apparently is not present in virgin soils.

At the Oregon station excellent protection from onion smut was secured by the use of formaldehyde, 1 ounce to 1 gallon of water, in a stream of not less than five-sixteenths of an inch in diameter, run into the furrow as the seed was dropped.

The New Jersey stations isolated an organism from peas affected with root rot that reproduced the disease by inoculation. Studies at the Utah station showed Pythium (probably *P. debaryanum*) to be the primary cause of root rot associated with Rhizoctonia and Fusaria.

The Georgia station found the fruit rot of peppers to be a bacterial spot disease. It was successfully transferred from peppers to tomatoes and back again. In studies on pepper mosaic it was found that aphids become a factor in the spread of the disease after it has started in the seed bed and in the field, but do not carry over the infection from one season to another. The spores of pepper leaf spot disease were found to be carried from one season to the next on the surface of seeds. In studies on the Sclerotium wilt of peppers at the Louisiana station about 5 per cent of potato plants were found to be infected with the disease, although only usually about 1 or 2 per cent are attacked. It occurs also on beans and has a wide range of hosts. The New Mexico station found that excessive heat and a high percentage of soil moisture are factors which help to develop disease in the Chili pepper.

Apple diseases.—For the control of apple anthracnose the Oregon station got the best results by the use of Bordeaux in one of the late codling moth sprays.

The Virginia station found apple black root rot to be largely due to *Xylaria digitata*, but *X. polymorpha* is also sometimes concerned, climatic conditions determining the prevalent species.

Studies at the Indiana station of the cankers produced by apple blotch showed that about 95 per cent occurred at leaf scars and was the result of leaf petiole infection and subsequent invasion of the twig through the petiole. Bordeaux mixture prevented petiole as well as fruit infection.

The Missouri station found that in most cases cleaning and sterilizing apple canker with bichlorid of mercury, mercuric cyanid, and other applications were ineffective.

Studies on apple rosette at the Washington station showed this to be a physiological trouble found only in alkali soil districts and practically always disappearing within three years after an orchard is planted to a legume cover crop. Chemical analysis showed the rosette twigs to have a much higher ash and nitrogen content than normal twigs.

Tests of means of control of apple scab at the Indiana station showed liquid lime sulphur to be more effective than dust and dusting to be more expensive than spraying. At the New Hampshire station Bordeaux mixture, copper acetate, or lime sulphur gave satisfactory control. Copper acetate was used at the rate of 2 pounds to 50 gallons of water, with 10 pounds of lime. Adding sugar to the mixture increased the injury to the foliage, especially when the amount of lime was high. The best control was secured by using sprays in the prepink stage. At the Montana station lime sulphur was succesfully used instead of Bordeaux in the control of this disease, the latter causing injury to the fruit.

Studies on frog-eye of apple leaves at the West Virginia station indicated that there are several fungi capable of causing this disease.

Peach diseases.—Studies at the Maryland station showed that Sclerotinia fruit rot of peaches is carried over winter both in mummied peaches and twig cankers.

Investigations on peach yellows at the Delaware station resulted in failure in all attempts to produce the disease by inoculation of healthy trees with diseased sap or emulsions of materials from infected trees. The pollen from infected trees was found to be weak and not able to pollinate healthy flowers. Premature fruit was the earliest evidence of yellows. June drop was not found to be due to faulty pollination or fertilization of the cell. Fully developed embryos were found in all specimens of dropped fruit.

At the Georgia station cross inoculations of peach rosette were made from the peach to the plum, peach to apricot, apricot to peach, peach to Mazzard cherry, almond to peach, and other combinations. The Marianna plum is apparently immune to the disease.

Citrus diseases.—At the California station citrus blast was found to be caused by the same organism that causes citrus black pit. It is spread by winds and gains entrance through slight injuries in the tree. Trees protected from the wind were not so much affected. Methods of control were perfected.

The Florida station found that the fungus *Phomopsis citri* grew best on a medium of 2 per cent solution of starch as a carbohydrate and filter paper as a source of cellulose. It did not grow in cultures to which a few drops of oil of orange had been added. In inoculation experiments the fungus produced melanose only on young tissue, leaves 2 or 3 weeks old being very susceptible; but those 4 to 8 weeks

old were very difficult to infect. Similarly, after the fruit had reached a certain stage, it was no longer subject to melanose spotting. The inoculation period ranged from four to seven days, generally five, and young fruits inocluated with the disease showed infection in four or five days. Early spraying with a 3–3–50 Bordeaux mixture, with the addition of 1 gallon of oil emulsion to 50 gallons of spray, gave excellent control. This station also studied stem end rot of citrus, and found that where this disease was present the abcission layer in the fruit had already formed and that apparently a fruit can not be infected with the disease until the abcission layer is formed.

Studies on the internal decline of lemons at the California station showed that prevention of the trouble lies in a uniform and liberal supply of water during periods of severe, hot, dry weather.

Other fruit diseases.—In studies at the Colorado station of a bacterial disease of the Wragg cherry, spots on the leaves similar to those occurring on naturally infected trees were produced by spraying with cultures of *Pseudomonas pruni*. It appeared to carry over in the twigs and apparently had some connection with hail injury, varying much in different seasons. The plum and peach were also found to be susceptible. At the South Carolina station, good results were obtained in the control of cherry leaf spot on eight varieties of sour cherries by spraying with Bordeaux mixture 2½–6–50, the first spray immediatly after the leaves had fallen, the second three weeks later, and the third directly after picking the fruit.

Studies at the Georgia station indicated that several species of Glœosporium and Colletotrichum may cause fruit rots. One form was found that attacks green fruit and also infects the leaves. One organism was found on the cotyledons of seedlings, indicating that it may be seed-borne, and some of the organisms were found to live on leaves of the plants until fruit was set. Inoculations of seed with spores from a phoma rot resulted in infected seedlings. The Maryland station isolated a number of strains of the brown rot fungus, which differ morphologically but not in virulence. They were found to develop the apothecial stage only when near the surface. Their development took place to a considerable extent during the first year, but in the greenhouse it sometimes required only a few weeks. The disease attacks nearly all fruits and the mode of entrance is mainly through wounds made by insects.

Mosaic.—Investigations at the Iowa station showed that mosaic of certain species of Cucurbitaceæ, Leguminosæ, Solanaceæ, and Labiatæ are interchangeable. Mosaic of tobacco, potatoes, and tomatoes can cross over to cucumbers, beans, and other crops. Many wild perennial plants, as wild ground cherries, milkweeds, and smartweeds, may serve as sources of spring infection in the above crops. Aphids, the striped cucumber beetle, and mealybugs act as carriers of the infective principle in the greenhouse. The Wisconsin station found that, although relatively high temperatures are most favorable for tobacco mosaic, relatively low temperatures (57° to 65° F.) are most favorable for the development of the disease on the potato. Above 77° the symptoms of the disease disappeared rapidly.

Texas root rot.—The Texas station found that the causal organism of Texas root rot is carried through the winter on susceptible living host plants, including cotton, tie vine, okra, pepper, castor bean, and many other plants, the roots of which remain alive during the winter

even after the tops are killed back by frost. The fruiting stage (*Phymatotrichum omnivorum*) of the root rot fungus was secured in cultures but was found to be very rare in the field. This is a summer stage only, and the spores will not germinate. Artificial inoculations with this fungus reproduced the disease on cotton. A large number of susceptible plants were found, including fruits, berries, truck and field crops, and ornamentals.

Chlorosis.—In experiments at the Delaware station with wheat, corn, and soy beans chlorosis due to insolubility of iron occurred with all concentrations over pH 6. At the New York Cornell station chlorosis was found to be due in part to accumulation of sugars.

Other diseases.—Studies at Utah station showed a soil temperature of 18° C. to be most favorable for the pathogenic action of *Corticium vagum*, which closely approximates the optimum temperature for the general development of its host, the potato.

Studies on the European canker at the Oregon station showed that the Fusarium stage of the fungus appeared in the fall after the rains set in, and the Ascochyta stage appeared in December, the spores being shed from that time until spring. Infections were obtained by inoculating broken tissues of Anjou pears with cultures of the fungus, best inoculations being obtained in January. Natural infection was brought about usually through pruning wounds or leaf scars. Spraying in the autumn with Boadeaux mixture controlled the disease.

Response to environment.—Studies at the Wisconsin station on the susceptibility of wheat and corn to the wheat scab organism showed that wheat seedlings blight in a comparatively warm soil, and corn blights in cool soil. The response to soil moisture, irrespective of the temperature, was the same, dry soils being most favorable. The composition of the wheat and corn seedlings evidently had some bearing on this, for it was found that wheat seedlings in a low soil temperature and corn seedlings in a high soil temperature were both characterized by being high in available carbohydrates and low in available nitrogen, and large amounts of available sugar were being rapidly converted into cellulose. The studies indicated that disease resistance and predisposition to resistance, in this case at least, may have been largely dependent upon the environmental conditions under which the plant was grown.

Fungicides.—At the New Hampshire station sulphur was found to be toxic only when in the presence of oxygen, and was more active at high than at low temperatures. Sulphids were extremely toxic, but the polysulphids decomposed rapidly on drying and their value was merely a contactual one.

ENTOMOLOGY

Orchard fruit insects.—Studies of the green aphis on apples at the West Virginia station indicated that it is not safe to take the activity of the tree as an index to the condition of the aphis eggs and as a basis for establishing dates for treatment. The Idaho station reports good control of the apple leaf roller with two sprayings, one when the trees were in a full pink stage and a second, calyx spray. Arsenate of lead, 12 pounds to 200 gallons of water, or Paris green, 6 pounds to 200 gallons, with lime added to prevent burning, gave good re-

sults. At the Pennsylvania station, late summer sprays of arsenate of lead, toward the end of July or the first of August, proved very successful in controlling the late-feeding generations of the leaf roller. Good control of the apple flea beetle was secured at the Ohio station by winter plowing and cultivation. The Oregon station secured best control of the apple blister mite with an oil emulsion consisting of 2 gallons of oil in 100 gallons of lime sulphur.

At the Maryland station tests with an emulsion of paradichlorbenzene in creosote proved effective in control of the peach borer and did not injure trees on drained land. The Michigan station found an effective repellent for the borer to be a mixture of soap, naphthol, flour, and sugar cooked together. Details of the treatment with paradichlorbenzene were studied at the New Jersey stations. On wet soil the effect was greatly interfered with. Temperature was also a factor. In a dry soil, at a temperature of 60° F., 4 inches below the surface, three weeks were required to get the full effect: while at 70° only two weeks were required. Fall treatment proved preferable. The North Carolina station showed that by clearing up around the orchards, applying four sprays during the season, and picking up all the dropped fruit, peach curculio injury could be reduced to a negligible quantity.

The Oregon station found that the pear leaf blister mite also attacks the apple and appears to injure the mountain ash. A combination of lime-sulphur, 1–12, plus oil emulsion, 2–100, was highly efficient, and early applications for its control on the apple are recommended.

Studies at the California station showed that the same species of codling moth attacks both the apple and the walnut and shows no choice of food plant. Spraying with lead arsenate showed a higher efficiency at less cost than dusting, one application in June being sufficient for walnuts. The Colorado station found that the average time of development of the codling moth, from egg to egg, varied from about 50 to 60 days. The most efficient control was secured by spraying with arsenate of lead, three to five applications being necessary. Picking and destroying all wormy apples is recommended. At the Idaho station it was found that 73.3 per cent of the spring brood transforms to moths, the remaining 26.7 per cent entering hibernation. The New Jersey stations report that it is necessary to keep apples coated with poison in order to control the moth. The New Mexico station found four broods a year in that State, the fourth brood overwintering. The largest deposits of eggs were found in July and August. With six sprayings, from 80 to 90 per cent of sound fruit was obtained. One and one-half pounds of arsenate of lead to 50 gallons of water is recommended, the first spray being given during the last of April or the first of May, or when 90 to 100 per cent of the petals have fallen, the second 15 days later and repeated after 46 days and 66 days, respectively, thereafter. Most of the invasion was observed to be through the sides of the fruit. At the Oregon station dusting generally gave control comparable with that of liquid sprays. The addition of spreaders improved the control. The Washington station reports that lead arsenate proved to be better than calcium or magnesium arsenates. The addition of a spreader at this station did not appear to increase the efficiency.

Studies of tent caterpillars at the Oregon station showed the percentage of parasitism to vary from 30 to 90 per cent, the major parasite being an undetermined Tachinid fly.

The Arizona station reports successful control of the date scale by burning over the trees with a torch after defoliating them, the trees recovering from the treatment in about three years.

Small fruit insects.—At the Washington station it was found that almost complete extermination of the cranberry fireworm may be secured, without serious injury to the plant, by spraying the eggs with a miscible oil. Fumigation under cover with carbon disulphid for the larger vine weevil on cranberries was not successful. At the New Jersey stations the cranberry girdler was controlled by three days' flooding in August, less damage resulting to the plants from shallow flooding.

The Kentucky station found that there are apparently various forms of the grape leaf hopper, one feeding on the sycamore as well as on the grape.

Studies at the Wisconsin station showed that the raspberry cane borer, which is doing considerable injury to the crop in the State, can be held in check by carefully pruning the canes below the gall caused by the borer and burning the cuttings.

The Tennessee station reports that the strawberry weevil does very serious injury in parts of that State. Contrary to observations farther north, the insect winters over in the woods, and there is a much larger number of host plants. New beds and those in the vicinity of woods are most often injured. The weevil was found to cut and to breed in the buds of the apple, a hitherto unreported host plant. The newly emerged adults were also found to injure buds of tomato and cotton. Studies on the strawberry crown borer at the same station showed that this insect has become so numerous in the State as to seriously interfere with the production of runners. It was found to feed upon the blackberry and was bred experimentally upon *Duchesnea indica* and *Potentilla primula*. Old and abandoned strawberry patches appeared to be the chief source of infestation, the life cycle being ordinarily one year. Egg laying begins in March, the egg stage lasting 18 days, the larval stage 39 days, and the pupal stage 11½ days. The insect is unable to emerge when buried 3 to 6 inches deep in moist, compacted soil.

In studies at this station on the strawberry root louse it was found that egg laying begins about the middle of November and lasts until January 1. The first eggs hatched in the field the middle of February and continued from then until November. Reproduction was observed to be parthenogenetic. Plants that were kept heavily infested during the summer produced as many runners as uninfested, sprayed plants. This may be explained by the presence of parasites which appeared as soon as the lice became at all abundant, especially a fly, *Paragus bicolor*, which has not previously been recorded as an enemy to the strawberry root louse. Two new parasites were found, a syrphid fly (*P. angustifrons*) and a small wasp (*Diaretus fuscicornis*). A new ant (*Pherdole vinlandica*) was found to attend and protect the lice, but it was not found so often on the roots as on the crown and leaves.

Pecan insects.—At the Mississippi station May beetles belonging to the genus Phyllophaga were found to cause serious injury to pecans.

Of the 42 species occurring in the State, 22 were found feeding on the pecan. The Texas station controlled the pecan case-bearer or bud moth by spraying with arsenate of lead, 3 pounds to 50 gallons of water.

Insects of ornamentals.—At the Maryland station molasses and nicotin sulphate proved quite effective in controlling the boxwood leaf miner and did not injure the foliage. It was necessary to repeat two or three times and after rains. The station also found that the chrysanthemum midge may be controlled with a spray of nicotin sulphate and soap, applied every fourth day during the egg stage, followed by semiweekly spraying during the adult stage. There were found to be four broods in the spring and three in the fall. The midge was found to live over winter out of doors in old plants, which should therefore be destroyed.

Field crop insects.—The Texas station found that the alfalfa weevil can be controlled by grazing the fields with sheep in the late fall. The Idaho station reports that a parasite (*Bathyplectes curculionis*), introduced in 1921, has become established and seems to be assisting materially in controlling the insect.

At the New York Cornell station it was found that the clover seed midge, which has two broods a year, can be largely controlled in the second brood by cutting the first crop early so that this brood has no green material to feed on.

The Virginia station controlled the larger cornstalk borer by plowing the corn stubble in December, harrowing immediately, and leaving the soil undisturbed until the following March. The Oklahoma station found the corn plant louse (*Aphis maidis*) on the dock. It differed on different host plants, a considerable list of which was noted, including practically all of the cereals.

A method of boll-weevil control based upon removal and destruction of all squares at time of emergence of the weevils, followed at once by thorough application of calcium arsenate or lead arsenate, was evolved and tested by the Florida station with results indicating that the method will insure at least 90 per cent of a normal crop at a cost for treatment of less than $2 per acre. The South Carolina station showed that the hand duster can be satisfactorily used on small farms to control the cotton boll weevil. The effectiveness of calcium arsenate dusting varied in different localities, depending upon the amount of infestation, quality of the land, climatic conditions, and other factors, but in general it was profitable in all sections of the State. Two parasites were reared at the North Carolina station, one being common and killing about 13 per cent of the weevils in the field.

The Arizona station found that the moth of the Thurberia cotton bollworm occurs on wild cotton but will not deposit eggs on tame cotton. The native boll weevil infests tame cotton but the bollworm does not, although the larvæ of the latter will live and develop on tame cotton. Life history studies of the bollworm indicated five instars, with 6 or 7 days for the egg stage, 1 month for the larval stage, and 10 months for the pupal stage.

The Oklahoma station found that the cowpea louse is the same as the melon and cotton louse, and that it has 40 to 50 other host plants, It occurs on citrus, and an oviparous form is found on the straw-

berry, but the eggs are sterile. These are all forms of *Aphis rumicis*. but vary so widely for each kind of plant that different descriptions are necessary. Spraying with hydrate of lime with 5 per cent nicotin sulphate gave good control.

The Iowa station showed that there is considerable varietal difference in susceptibility to the potato leaf hopper and hopperburn, Rural New Yorker and Early Ohio being quite resistant, while Bliss Triumph and Irish Cobbler are more susceptible. The disease was largly controlled in northern Iowa by planting a resistant variety comparatively late in order to escape the spring flight of the hoppers, and spraying at least three times with a 4–6–50 Bordeaux mixture. Determining factors in immunity appeared to be succulence and the rate and period of growth, the high degree of immunity of Rural New Yorker being due apparently to the fact that it is not especially succulent, has a rather tough skin, and is slow growing and has a long growth period. Date of planting also exerted a decisive influence, late plantings (June 14) showing no hopperburn, whereas the earlier plantings succumbed. Dusting three times with copper arsenate failed to give satisfactory control. The New Jersey stations found that although dusting will repel the potato flea beetle, an emulsion of carbon disulphid and fish-oil soap promises to be a killing mixture. Tests at the Wisconsin station showed nicotin dust to be 100 per cent efficient against the flea beetle.

The Kansas station found chinch bugs hibernating on Sudan grass. *Aphis maidis* was found to attack sorghum as well as corn and to affect the germination of the seed. Hybrids of milo and sorghum were found to be resistant to chinch bug injury.

Studies on the sugar-beet louse by the Utah station showed that by May 15 the maggots had worked to the surface and pupated, the flies beginning to come out by June 1 and to oviposit on the underside of the leaves, producing full-grown maggots by July 1. There was only one brood a year. Many weeds were found to be host plants. It was also found that the insect withstands much dryness as well as moisture.

The California station secured evidence indicating that curly leaf of sugar beets is not produced by a toxin injected into the beet by the leaf hopper. The incubation period in the beet was found to depend upon the size of the beet. It was not possible to reduce the incubation period in the hopper to less than four hours. The minimum incubation period of the infective principle in the leaf hopper was four hours at a mean temperature of 100° F. and in the sugar beet three days at a mean temperature of 80.3°. The leaf hopper was not infective when it hatched. Some of the nymphs molted six times under high temperature and five times under low. It was not demonstrated that the hopper was a mechanical carrier of the disease.

Leaf hoppers which had fasted and whose mouth parts were contaminated with *Bacillus morulans* isolated from diseased beets, when allowed to puncture a healthy leaf failed to transmit the disease as did those which were allowed to inject into the tissues bacteria rubbed on a portion of the beet leaf. Daily inoculations of juice from beets upon which the hoppers had fed for from one to eight days, or until the earliest symptoms of curly leaf appeared, failed to produce the disease in healthy beets; and juice exuding from diseased beets in the field gave negative results when inoculated into healthy beets.

The excrement when injected into the petioles of healthy beets did not produce the disease. It was not transmitted through the seeds from stechling beets affected with the disease before and after transplanting.

The hoppers overwintered on Alfilaria and Atriplex and also bred on *Chenopodium morale.* Thirty-five host plants have been found to date. The hoppers did not breed where the climate was moist. Five broods were recorded in the San Joaquin Valley and only two in Salinas Valley, where there is more fog. Dusting with a mixture of kaolin, lime, and 10 per cent of Black Leaf 40 showed a large reduction in the number of hoppers. It was most effective when applied shortly after the spring invasion of the beet fields by adults. Three egg parasites were found.

The Montana station found about a dozen species of insects attacking the native sunflower that readily go to the cultivated plant and cause considerable damage. The Colorado station found that the sunflower aphis winters on the dogwood, and is best controlled by spraying this host.

The Texas station observed flights of 100 yards by the sweet potato weevil in the field, and this must be considered as a means of dissemination. As control measures, clean culture, quarantine, prompt and proper harvesting, and rotation are recommended. Studies of the effectiveness of overflows and submergence for control showed that the adult weevil may remain alive, floating on the surface of water for 216 hours, and that the immature weevils are not easily affected by submergence.

Investigations at the South Dakota station showed that the wheat-stem maggot pupates within the leaf sheath of the wheat plant about an inch below the ligule. Infected plants may be recognized when mature by the white heads and spreading awns. Parasitic control seemed to be of some importance.

Insects affecting vegetables.—The Wisconsin station reports control of the striped cucumber beetle by two or three thorough applications of dust containing 10 per cent nicotin sulphate, the first application being made early in June. Flight tests showed that this insect seldom flies over half a mile. There are two generations of the beetle in Wisconsin and sometimes a partial third. In studies at the Arkansas station, migration of this insect occurred early in the spring, and after settling they did not move much. Powdered arsenate of lead, 2 pounds to 50 pounds of lime, mixed with a little molasses, was very effective in control.

The Florida station worked out the life history of the bean Jassid (*Empoasca mali*) for that State, and devised a new type of spraying machine, which is very successful in its control. Studies on the bean weevil at the New Jersey stations showed that ball clay is an effective protection when used in the proportion of 1 part of clay to 10 parts of beans. The same material successfully protected corn against the grain moth when used at the rate of 1 part of clay to 50 parts of corn. At the Colorado station, the Mexican bean beetle was found to winter as an adult and to come out of hibernation the middle or latter part of June. There was one main life cycle, but a few passed through a second cycle. The maximum injury was observed in the latter part of July and during August. The most satisfactory control tested was spraying with arsenate of zinc (1 pound to 50 gallons

of water) or arsenate of lead (1 pound to 40 gallons), care being taken to apply the spray to the under surface of the leaf. One, two, or three sprayings may be necessary and early planting is desirable.

At the Maryland station, dusting with 5 per cent of nicotin gave excellent control of the pea aphis, dusted fields giving almost double the yields of undusted. The Wisconsin station found that although the first, second, and third nymph stages of the squash bug were readily killed with nicotin dust, the fourth and fifth nymphs, eggs, and adults were quite resistant.

Aphids.—At the Kansas station studies of the wing development of *Aphis prunifolia* showed that if the mother is winged, the progeny are wingless, and vice versa; if the mother is starved, the progeny are winged.

The Texas station, studying the factors determining the production of wings on aphids, found that at a temperature of 65° F. aphids generated without winged forms. Chemical and food conditions also had an effect. The male melon louse was not found.

At the Maine station two species of aphids troublesome on currants and gooseberries were found to migrate to willow herbs, on which the summer generations were passed. The alternate host of the pink and green potato aphis, a carrier of potato mosaic, was found to be the rose; and it is believed that by the destruction of rosebushes in the vicinity of potato fields this disease can be largely controlled. Although other insects may transmit the disease, in Maine at least this aphis is apparently the most important one.

Bees.—Observations at the Iowa station showed that when white clover was abundant and the weather favorable, workers made an average of 13 trips daily, while on unfavorable days only about eight trips were made. The average time spent in the hive by a bee returning from gathering honey or pollen was three or four minutes. The maximum load of nectar was found to be 85 per cent of the bee's weight, with an average of about 50 per cent. Observations indicated that only about 20 per cent of the bees in the hive were actually engaged in gathering nectar and honey. The highest observed speed of bees in flight was 25 miles per hour, but the average was considerably below 20 miles.

A survey of honey plants at the Kansas station showed that alfalfa does not produce nectar below 1,000 feet altitude. At the Minnesota station, Carniolan bees swarmed more than the Italians in the same-sized hive. The brood area on June 1 was in the proportion of 13 to 16 in favor of the Carniolans.

The Wisconsin station found a solution of sodium hypochlorite highly efficient in disinfecting hives and equipment, as well as for treating foul brood, by feeding sirup to which it had been added.

In investigations on the poisoning of bees by arsenical sprays, the Washington station found soluble oils and nicotin sulphate effective repellents when added to sprays.

At the Wisconsin station it was found that wintering colonies maintained a fairly constant temperature around the outside of the cluster, ranging from 57° to 60° F., regardless of how cold the weather was. As the temperature went down, the bees developed a higher temperature within the cluster by muscular activity; but if the low temperature was maintained very long, the bees were unable to resist and eventually died.

Grasshoppers and crickets.—The South Dakota station observed that there is usually but one brood of crickets a year in that State, and that there are from 9 to 11 stages in the life cycle. Two forms of *Gryllus assimilis* were found, one that hibernates in the egg stage, this being the most common, and one in the nymph stage. The eggs hatch from late in May to the middle of June. The two principal methods of control worked out were destruction of the eggs through cultivation, disking, or plowing, and killing the crickets with poison baits consisting of 20 pounds of bran, 2 quarts of blackstrap molasses, 1 pound of white arsenic or Paris green, and 3½ gallons of water. The control measures were most effective during July. The adult forms appear early in August. About 50 per cent of the eggs collected were parasitized. The Montana station found that poison bran was most effective for grasshopper control when applied from 7 to 11 a. m. The Oregon station found the most attractive bait to be bran and old sawdust in equal parts, with molasses, salt, white arsenic, and amyl acetate. When sodium arsenate was substituted for white arsenic, the bait appeared less attractive but killed in about half the time. The Wisconsin station found that sawdust could be substituted for bran in the bait, reducing the cost about one-half without diminishing the efficiency.

Cutworms.—The pale western cutworm, according to the Montana station, caused an estimated loss of 200,000 acres of grain in that State, valued at $3,000,000, in 1919. Summer fallowed fields, cultivated early to kill the weeds and not cultivated after July 15, became crusted over and were surprisingly free from cutworms. Spring grain seeded on very early spring plowing was seldom injured. Irrigation gave practically complete control. The North Dakota station found this insect to lay eggs mostly in August in wheat fields where the ground was quite loose. No crop, with the possible exception of sweet clover, was exempt from injury by this insect; but little or no damage followed such crops as late millet, late flax, corn, or potatoes.

The most troublesome species of cutworm observed by the North Carolina station was *Feltra gladiaria*. These were found to be readily checked or killed during the pupating stage by the slightest disturbance, thus suggesting summer cultivation as a control measure.

Flies.—Two new species and one new genus of the parasitic flies, Tachinidæ, were reported by the Texas station, one of the new species being parasitic on the cricket and one on the snail. The size was found to be dependent upon the food supply, and the color varied in the same species in different localities. The size and arrangement of the bristles varied considerably.

Soil insects and nematodes.—In investigations at the Washington station of various soil fumigants placed under ground and examined a few days later, in no case did the insecticides show any long-range effects, dead insects being found only within a radius of a foot or so from the point of administration.

At the New Hampshire station tobacco dust lime mixture used dry killed 100 per cent of the eggs or of the emerging larvæ of root maggots. There was, however, very little repellent action, although adult flies were found not to lay eggs freely on or near plants freshly treated with the mixture, and such eggs as were laid in contact with the mixture did not hatch. Protection rapidly diminished, however, when rains intervened. It was most important to protect the plants

during the first two or three weeks after they were set out. The treatment was successsful with cabbages, radishes, turnips, and cauliflowers.

The Florida station obtained striking results in the control of nematodes by summer fallowing in connection with growing a crop of bush velvet beans, which are practically immune. In seed-bed treatment with sodium cyanid and ammonium sulphate, better results were obtained by covering the bed with a gas-proof material, of which "balloon cloth" proved the best, giving better killing not only of the nematodes but also of other soil insect pests and even of Bermuda grass.

Scale insects.—The Mississippi station reported the occurrence of 82 species of scale insects in the State, not including some undetermined species. Tests with the San José scale at the Arkansas station showed that the common practice of using lime-sulphur as a winter spray is not as good as a spring spray. The December and January spray gave an 80 per cent kill, while a March spray gave 100 per cent. Tests of dry lime-sulphur and a number of proprietary insecticides at the Missouri station indicated that, although it was impracticable to eradicate San José scale from infected peach trees, proper application of most of the materials gave good results. In experiments with the oyster shell scale at the Indiana station, good control was obtained even in heavy infestations by spraying with whale-oil or fish-oil soap, 1 pound to 5 gallons of water, with the addition of an ounce of 40 per cent nicotin sulphate.

Stored products insects.—Studies at the Kansas station showed that the yellow and dark meal worms (*Tenebrio molitor* and *T. obscurus*) have a life cycle of one year when fed on flour, but a longer cycle when they are fed on bran. The West Virginia station found that very few weevils, moths, grain beetles, and other stored products insects were able to withstand a constant temperature of 35° C. (95° F.), although they may withstand temperatures up to 50° C. for a short time. Continuous temperatures of 90° to 95° F. killed all insects tested, but if the temperature was lowered occasionally 10° to 20° their development was normal. The Ohio station found an efficient method of killing insects in stored cereals without lessening the germinating power of the seed to be the maintaining of a temperature of 130° to 140° F. for four days.

Miscellaneous insects.—Life-history studies of the cheese fly at the California station showed that from 36 to 48 hours are passed in the egg stage, 8 to 15 days as a larva, 7 to 12 days as a pupa, and from 4 to 7 days' preoviposition period. In tight cheese rooms, 10 ounces of sodium cyanid per 1,000 cubic feet with 24 hours' exposure at 65° F. or above killed the adult cheese fly, pupæ, and exposed larvæ, and also cheese mites. The fumigation should be repeated two or three times at two-week intervals. Cheese exposed to the fumigant showed no appreciable evidence of absorption of the fumigant after a few hours' aeration. The Oregon station secured highly efficient control of the European earwig through the use of a poisoned bran bait, with sodium fluorid as a toxic agent.

The European red mite was shown by the Maryland station to be the same as the citrus mite. It was found to be especially serious on apples, but also laid eggs on the peach, the leaves of infected trees

losing their green color. Summer spraying with miscible oils proved quite effective in its control.

A study of the larger plant bugs at the Florida station showed that the seasonal activities of their parasites were practically the same as those of the insects. Sunflowers were found to be somewhat effective as a trap crop. Spraying for control of thrips on citrus was most effective when done in the height of bloom. Spraying did little good unless weeds were cut in orchards during the winter. Oranges were more severely injured by the insect than was grapefruit. The addition of nicotin sulphate to Bordeaux lime-sulphur increased its efficiency for use on grapefruit trees at blooming time. Liem-nicotin-sulphate dust was effective only when put directly into the bloom.

The Florida station reported a successful method of growing the brown fungus parasite of the white fly in cultures in a medium prepared from grasshopper soup, hardened with gelatin. This fungus was found to be a more efficient parasite than the red fungus.

The Idaho station found eight species of the false wireworm (Eleodes) in eastern Idaho, only one (*E. hispilabus*) occurring abundantly. The eggs are laid mostly in June and have an average incubation period of 135 days. The larvæ were found doing serious damage to both spring and fall planted wheat, one count showing them to occur at the rate of 2,537,200 per acre. Indications are that they remain in the soil about one year before transforming into beetles. They were successfully controlled by use of a poison mash made of bran, Paris green, amyl acetate, and water, applied as the beetles emerged and before they began egg laying.

Insecticides.—The New Jersey stations found that crystalloid carriers evolve nicotin much more rapidly than colloidal carriers, especially if the crystalloid is a carbonate. Fifty pounds of 1.5 per cent nicotin dust evolving 40 per cent of gas in 48 hours killed 90 per cent of aphids by asphyxiation.

The Minnesota station showed that for the control of grain insects a mixture of 90 per cent carbon tetrachlorid and 10 per cent chloropicrin was more toxic than either one alone. In a comparison of Bordeaux and copper arsenate dust, the dust proved almost a failure in controlling leaf hoppers on potatoes, but was fairly efficient in controlling some orchard pests.

The Oregon station showed calcium caseinate to have many advantages as a spreader for spray solutions. Its addition to combination sprays of lead arsenate-lime sulphur materially delayed the reaction between the two materials and the formation of an undesirable sludge. Used in the late cover sprays on apples, it minimized the uneven coloring of the highly colored varieties of fruit by forming a smooth, even covering over them. It tended to increase the number of trees covered per tank of spray and there was no evidence that it adversely affected the toxicity of the arsenical spray.

The Pennsylvania station found that dusting was as efficient as liquid sprays for control of plant lice on rutabagas, and field tests showed the covering of the under sides of the leaves to be more uniform with the dust.

Slugs.—The gray garden slug was reported by the Oregon station as causing severe injury to fields of clover, rye, and oats. Two hundred mesh dehydrated copper sulphate dust and Bordeaux dust

killed every slug hit. Eight pounds of dust to the acre appeared to be sufficient. Copper carbonate dusts were not equally effective.

BEEF CATTLE

The age factor.—Tests at the Arizona station showed that it costs only about half as much to put on gain with calves as with older cows. At the Missouri station the younger cattle made somewhat more economical gains than the older and more mature cattle; but since they grew as well as fattened, they were not put in marketable condition as quickly as older cattle. At the Nebraska station more economical beef was produced by calves than by older cattle. Calves made as much gain of beef from 61 pounds of feed as 3-year-old animals made from 100 pounds. Young cattle made more constant gains over long feeding periods. Better-bred cattle made larger gains at less cost. The use of supplements did not prove economically profitable.

Changes in body composition.—The Missouri station found in general that the percentage of fatty tissue increased and of bone decreased with age and fatness. The composition of the carcass became fairly constant at 8 to 10 months of age. The total nitrogen did not materially change with the condition of the animal. The nitrogen increased with age at apparently three periods—3 months, 3 to 12 months, and 12 months to maturity. The proportion of soluble nitrogen of the lean flesh tended to increase as the animal matured. Starvation withdrew the soluble nitrogen from the flesh. The proportion of soluble phosphorus tended to increase as the animal grew thinner, and the soluble ash increased somewhat as the plane of nutrition was lowered and decreased with age and fatness of the animal. The increase made by mature animals was nearly all fat.

Planes of nutrition.—The Missouri station found that if a steer was stunted for two years and then fed it would attain normal growth; but if stunted for a longer period normal growth was not restored. Other things being equal, steers on a low-protein diet did about as well as those on a high one.

Baby beef.—In experiments at the Minnesota station purebred Hereford calves, grades, and common beef calves fed a standard ration of shelled corn, ground oats, linseed meal, and alfalfa hay gave satisfactory gains; but the addition of a full feed of corn silage kept them more regularly on feed, and they consumed less grain and fattened faster at a reduced cost. In a lot receiving barley as a substitute for shelled corn, the gains were more rapid in the early period of feeding, but slowed down toward the end of the period, showing a decreased gain at an increased cost. The market quality of the purebreds and high grades was about the same. The common calves, which were very thin at the beginning of the experiment, gained more rapidly and on less feed than the others, but they did not finish as smoothly and sold for less per 100 pounds than the purebred animals. As the purchase price of the common calves was about half that paid for the purebreds, they gave the greatest financial gains.

Winter feeding.—The Montana station showed that calves can be satisfactorily wintered and grown on hay or hay and sunflower silage. A mixture of alsike clover and timothy hay was slightly superior to alfalfa alone. Except in cases of hay shortage with high prices and

relatively cheap grain, it was impractical to feed even a light grain ration to grade calves that were to be turned on grass the following season. With a medium grain ration, the calves were fatter than necessary for grazing purposes and not fat enough for killing purposes. This station also showed that if cows were in good condition in the fall they could be fed on mixed straw as the sole ration for the winter and produce strong calves, but if they were thin in the fall they would not do this.

The Oregon station found that young growing steers should hold their own during the winter, but large gains during the winter feeding period are neither necessary nor desirable unless they can be made economically.

Alfalfa hay.—At the Arizona station a Hereford cow maintained her weight and condition on alfalfa hay alone for four years. The Idaho station found that cutting alfalfa hay effected a saving of nearly 30 per cent of the hay and 13 per cent of the barley required to produce 100 pounds of gain.

Silage.—At the North Dakota station corn silage was found to be distinctly superior to sunflower, millet, and oat straw and sweet clover silages, both with reference to gains and finish of the steers. The Oklahoma station found that sunflower silage combined with shelled corn, cottonseed meal, and alfalfa hay gave better results than corn, kafir, cane, and darso silages for making beef. Corn silage ranked a close second, and the corn silage lot outranked all others in returns when the pork produced by hogs following the steers was taken into consideration. Sunflower silage gave practically the same gains as corn silage in baby beef production. Steer feeding experiments at the Colorado station showed sunflower silage to be 75 to 81 per cent as effective as corn silage, but, on account of the higher yield, cheaper.

In comparative tests at the South Dakota station the average daily gain per head was largest with steers which received corn silage and smallest with those receiving sunflower silage. The daily gains were not increased by mixing the silages. At the Washington station when corn and sunflower silages were fed to cattle during a period of 90 days, on the basis of the same amount of dry matter, the gains from the two were practically the same, but the most profitable gains were secured from sunflower silage. In comparative tests at the Wisconsin station with 2-year-old steers, corn silage and sunflower silage gave practically the same gains. Hogs following the steers, however, returned a greater profit for the lot receiving corn silage. In six years' experiments at the Pennsylvania station, a combination of corn silage full fed, cottonseed meal 2.5 to 3 pounds, and a small quantity of corn stover without any corn gave the largest net profits. In experiments at the Idaho station 1,000 pounds of silage replaced about 449 pounds of alfalfa hay and 20 pounds of barley in a ration for cattle.

Corn as feed.—Results of a number of trials at the Indiana station favored the use of a full feed of corn in fattening 2-year-old steers. Least profit was obtained where a half ration of corn was fed. It was not profitable to add cottonseed meal to a ration of corn, clover hay, and corn silage if a ton of meal cost more than 100 bushels of corn. In a comparison of feeding broken ear and shelled corn at the

Kentucky station, it was found that the latter did not pay for the labor of shelling.

At the Minnesota station, ground barley equaled shelled corn, pound for pound, in producing gains in weight in fattening steers; but pigs following cattle fed corn made a considerable saving, while those following steers receiving ground barley made practically no saving.

Peanuts and beans.—At the Georgia station peanuts added to the ration showed no effect on the chemical composition of the beef. At the New Mexico station cull pinto beans, corn stover, and bean straw, with corn, gave good maintenance but small gains. If more than 4 pounds a day of the beans were fed, the animals scoured. The straw proved to be a good roughage, high in protein. It formed a very satisfactory feed for hogs and sheep, which did not scour. Tests at the South Carolina station showed that cattle fed velvet beans as the sole concentrate did not put on flesh rapidly but made economical gains.

SHEEP AND GOATS

Breeding.—The Idaho station found sex in sheep to be a matter of inheritance, as had previously been found to be the case with swine, horses, and cattle. In cross-breeding experiments at the Oklahoma station, the polled character of Shropshires was found to be dominant over the horns of Dorsets. The influence of the ram was found to be stronger than that of the ewe in determining fineness of fleece. At the Nevada station a comparison of lambs from range flocks using purebred or highbred bucks with those from flocks using scrub bucks showed a marked difference in growth in favor of the purebred bucks.

Shearing and docking.—The Texas station obtained a little more wool by shearing twice a year, but the fleece was less valuable than that sheared once a year. Tests at the Pennsylvania station showed that there was practically no difference in rate of gain whether the hot docking pincers or the emasculator was used, and that castration performed at the time of docking did not lessen the gains.

Feeding lambs.—The Nebraska station, comparing lambs fed on corn and alfalfa alone with those receiving supplements of silage, molasses, alfalfa meal, and linseed meal, found that the cheapest gain was made on corn and alfalfa alone. With a lot of lambs allowed to run in the cornfield for 90 days, as compared with the dry lot feeding of corn, alfalfa, and oil meal, the cheapest gains were made with the corn-fed lot. At the North Dakota station lambs turned in a cornfield with no other feed for 49 days made an average daily gain of 0.244 pound and required 9.7 pounds of corn per pound of gain. In a comparison at the Idaho station of corn, barley, wheat, and oats as grain supplements for lambs, corn proved a better feed than barley. Both wheat and oats showed less gains and poorer finish. Cut hay proved slightly better than uncut. Lambs receiving silage in addition to alfalfa hay made the best gain and finish. No advantage was found in withholding grain during the first 30 days of feeding. Experiments in fattening lambs at the Washington station showed that taking the hay from the first cutting of alfalfa as 100, the value of the second cutting was only 63, and of the third 85, while that of the first cutting of sweet clover, 24 to 30 inches high, was 123. A lot of lambs with which one-third of the concentrate (corn) was replaced with beet molasses made as good gains as those

receiving corn alone, but had a slightly lower finish. At the Texas station milo and kafir produced practically the same gains as ground shelled corn when fed in the same amounts. In a comparison at the Indiana station of linseed-oil meal and cottonseed meal fed in connection with leguminous hay and in limited amounts, cottonseed meal was superior to linseed-oil meal for fattening lambs; but, when fed in liberal amounts not in connection with legume hay, linseed-oil meal gave better results.

Feeding ewes.—At the Colorado station breeding ewes fed alfalfa hay alone, in combination with corn, sunflower silage, and beet-top silage, maintained their weight as well and made cheaper gains than those fed alfalfa. There was very little difference in the weight of lambs from the different lots, or in their gain from birth to finish. The use of sunflower silage was found by the Oklahoma station to reduce the cost of feeding pregnant ewes, but the ewes fed sunflower silage were slower in lambing, and the lambs were not so good as those from ewes receiving corn silage. The ewes fed sunflower silage were not as good mothers. At the Arizona station feeding three-fourths of a pound per day of whole cottonseed to pregnant ewes produced no ill effects. The Montana station found 3 pounds of sunflower silage to be equal to 1 pound of alfalfa hay as feed for ewes.

Wool.—In studies at the Wyoming station the rate of change in the weight of wool was comparatively low where large quantities were stored in one place. The weather was found to have a very destructive influence upon wool fiber, but very severe treatments of the sheep's fleece with alkali salts had no measurable effect upon the strength of the fiber.

Goats.—At the New Mexico station crossing native does with Toggenburg bucks increased the milk yield in the first cross about one-third, and in the second generation an additional 15 per cent. The best native does gave about 2 quarts of milk a day. Two-year-old half bloods averaged about 200 pounds more milk for the first seven months of their lactation period than native does.

SWINE

Breeding.—A comparison at the Missouri station, through 12 generations of sows bred at the first heat period with sows bred first when more mature, showed that pigs from early bred sows were later in reaching an equal weight; but there was no eventual difference in the pigs, and more litters were secured from early bred sows. Early breeding did not influence the inheritance of ability to grow and fatten. Sows fed on a high plane of nutrition gave the biggest litters which made the fastest gains. Low-plane pigs grew in height but not in weight as fast as those on a high plane. The Minnesota station found that spring pigs made slightly better gains for feed consumed than fall pigs.

Maintenance requirements.—The Missouri station calculated the maintenance requirements of swine on the basis of surface area to be as follows: At a weight of 125 pounds, 3.028 therms per square meter; at 175 pounds, 2.838 therms; at 225 pounds, 2.807 therms; and at 275 pounds, 2.498 therms.

Pasture and forage crops.—At the Montana station alfalfa proved to be the most satisfactory hog pasture, and brome grass next. The

addition of tankage to a corn ration for pigs on alfalfa pasture did not show appreciable advantage. At the Arizona station the best gains were secured on alfalfa pasture with a self-fed grain mixture of 90 per cent Hegari and 10 per cent tankage. The poorest results were made on alfalfa pasture alone. The Pennsylvania station, in a three-year comparison of rape, rape and oats, and rape, oats, and peas, for hog pasture, found that rape alone gave decidedly the best results as to the amount of feed and pork per acre. The South Carolina station found neither peanuts nor sweet potatoes to be as profitable for pork production as for sale. At the North Dakota station, March farrowed pigs did better on pasture than May farrowed litters. At the Idaho station feeding of field peas resulted in considerable trouble and loss from paralysis of the hindquarters. Feeding with skim milk or tankage for a short time corrected the trouble. At the Wisconsin station there was no advantage from adding mangels and yellow carrots to a good ration for brood sows. When fed alone their food value was low.

Hogging down crops.—In experiments at the Missouri station corn pastured by hogs supplied with tankage produced more pork, and the hogs gained more rapidly than on any other combinations tested; tankage with corn alone or with corn and soy beans materially increased the rate and economy of gain; soy beans with corn did not completely take the place of tankage; and hogs on corn with soy beans alone made slightly more rapid gains than those on corn alone, but produced little if any more pork. Similar tests at the Kentucky station showed that hogging down corn and soy beans was not so profitable as hogging down corn alone, with free access to tankage. At the South Carolina station an acre of soy beans hogged off produced 400 pounds of pork. A comparison of hogging and sheeping down corn at the North Dakota station showed better financial returns from the former.

Miscellaneous feeds and supplements.—At the Nebraska station shoats receiving corn supplemented with tankage, alfalfa, or shorts gave better gains than those fed corn alone in a self-feeder. The largest and most profitable gains were made on corn and alfalfa. The Washington station found cane molasses equivalent in feeding value to barley when fed with pea forage. In tests made at the Kentucky station, stale buttermilk fed to hogs showed no bad effects if care was taken as to cleanliness of the utensils used. At the North Carolina station no fishy taste was noted in meat from hogs that had consumed as high as 82 pounds of fish meal in 119 days. At the Wyoming station three lots of pigs were fed garbage alone, barley alone, and various combinations of garbage and barley. The garbage lot made the cheapest gains, the mixed lot next, and the lot with barley alone next.

Mineral supplements.—At the Indiana station soy beans were not found to be as efficient as tankage, fish meal, or buttermilk as supplements to corn, apparently because of deficiency of mineral matter in both the corn and the soy beans. A homemade mineral mixture, consisting of 10 parts of wood ashes, 10 parts of 16 per cent acid phosphate, and 1 part of common salt, fed at the rate of about 10 pounds of the mixture per 100 pounds of gain, increased the rate of gain 30 per cent and decreased the food requirements 13 per cent. In experiments at the Iowa station gains were more rapid, the appetite better, and the feed

requirements per 100 pounds of gain less in the lot receiving the supplement. A mixture of salt and high-calcium limestone in equal parts proved to be as good as more complicated mixtures. In tests at the Oklahoma station lots of hogs fed the same ration with and without mineral supplements made practically the same gains, but those receiving the minerals had much thicker and stronger bones.

Soft pork.—The Georgia station found that 100-pound hogs fed in dry lot or grazed on peanuts for 60 days or more made soft pork and could not be hardened by feeding corn and tankage or corn and cottonseed meal for a subsequent period of 60 days or less, thus confirming results obtained by the North Carolina, South Carolina, and Alabama stations. Unthrifty hogs were generally soft, and the younger and smaller the hog the softer the carcass. Tests at the Florida station showed a marked variation in the melting points of the fat of pigs in the same litter, also in the fat of pigs from different litters sired by the same boar. There was some indication that a low or high melting point of the fat may be hereditary. In experiments at the North Carolina station with varying amounts of peanut oil added to a basal ration containing no peanuts, there were gradations of softness of the pork, increasing with the amount of oil fed. At the Texas station all of a lot of pigs grazed for 57 days on peanuts alone produced soft pork; 3 out of 10 of a second lot, grazed on peanuts for 30 days followed by milo chops and cottonseed meal for 27 days, killing soft. A similar lot, fed milo chops and peanut meal in the self-feeder, produced hard pork.

In tests at the Oklahoma station feeding peanuts and other concentrates together for 70 days gave better results than feeding peanuts for 40 days and a finishing feed for 30 days. At the Missouri station sunflower seed fed alone produced very soft pork. When it replaced as much as one-fourth of a ration of corn and tankage, the fat was not soft. The Texas station found that rice bran with equal parts of corn chops and 10 per cent of tankage can probably constitute 60 per cent of a ration of corn chops and tankage without having the carcass graded as soft. The California station found that rice by-products do not produce soft pork in all cases, this varying considerably with the individual.

POULTRY

Breeding.—From a study of sex-linked characters in poultry, the Connecticut Storrs station found it possible, with 2,000 chicks from crosses of barred and red fowls, to separate the males and females at the time of hatching. By numerous crossings it was found that barring (Barred Rock type) masked spangling, spangling was hidden by black, and the sex-linked spangling pattern was dominant over or masked buff. Black fowls were found to be genetically buff plus the factor for the extension of black, since buff fowls appeared in the second generation from the cross of black and Columbian. Continued brother and sister mating at this station has resulted in a noticeable decline in vigor and a general slowing down in the rates of all life processes, such as growth, sexual maturity, and beginning of egg production. Outcrossing at the Idaho station with introduced strains of White Leghorns indicated that mixing strains within a

variety should be avoided, since the results may be poorer than those obtained with the original strain.

Egg production.—Of 2,544 Single Comb White Leghorn eggs graded at the Idaho station between March and October, the average weight was 63.1 grams, or 5.1 grams higher than the average weight of eggs on the market. Of the eggs, 87.7 per cent were chalk white, 10.1 per cent slightly tinted, 1.7 per cent cream, and 0.5 per cent brown. In texture, 74 per cent were normal, 22 per cent rough, and 4 per cent porous. In shape, 85 per cent were normal, 5 per cent round, 5.6 per cent long and slender, and 4.4 per cent irregular. Of 1,214 eggs candled, 34 per cent were transparent, 56.6 per cent cloudy, 39.4 per cent dark red, and 0.6 per cent bloody. The Iowa station found that, with pullets in their first egg-laying year, vigor, vitality, and constitution are of prime importance as indicating future egg production, and that early maturity is absolutely essential. A survey of the State showed that about 34 per cent of the hens in farm flocks are culls, and the average annual egg production per hen in the farm flocks is only about 60 eggs, due partly to poor feeding.

In a comparison, by the North Carolina station, of fowls from the same hatchings raised in North Carolina and in Winnipeg, Canada, the southern birds laid more eggs than the northern birds. Leghorns selected and bred for egg production produced 1 dozen eggs for each 6 pounds of feed consumed; and other breeds, unselected, averaged 9.6 pounds of feed per dozen eggs. At the Missouri station, of 67 pullets which matured in less than 200 days, 19 (28 per cent) laid more than 200 eggs each the first year; of 135 which matured in from 200 to 250 days, 11 (8 per cent) laid more than 200 eggs; and no pullet requiring over 250 days to mature laid over 200 eggs.

The Oregon station found that there was a close correlation between March and April production and annual production. Late laying in the summer and fall did not always indicate a good layer. On the average, there was a rather consistent decrease in production each year. There appeared to be a correlation between rate of laying and the fat content of the eggs.

At the Texas station there was found to be direct correlation between egg laying and the pliability of the pelvic bones. Hens with a thin pliable skin lay a large number of eggs. Early molters were poor layers. There was a positive correlation between capacity and weight and between depth of body and weight.

Hatchability.—At the Connecticut Storrs station the selection of mothers on the basis of percentage of fertile eggs did not result in the isolation of true breeding strains, characterized by high and low hatching qualities. Inbreeding brought about a marked decrease in the hatching qualities of eggs. The gross characteristics of eggs played but little part in causing differences in the hatching quality, nor was size of egg related to hatchability, although large eggs from an individual did not hatch as well as small. Porous eggs did not hatch as well as dense-shelled ones.

At the Wisconsin station, pullets fed a ration of white corn and casein gave an average hatch of 15 per cent of the fertile eggs, but by using yellow corn instead of white this was increased to 23 per cent. When feed rich in vitamin, such as pork liver, was added to the rations, the average hatch for the white corn lot was 53 per cent and for the yellow corn lot 62 per cent. With skim-milk powder in

place of pork liver, the white corn lot gave an average hatch of 21 per cent and the yellow corn lot 50 per cent.

The Kansas station showed that the individuality of the hen may have as much to do with the hatchability of eggs and the vitality of chicks as does the character of the feed.

The Nebraska station found a direct correlation between the weight of the egg and chick weight at hatching, the latter being about 64 per cent of the egg weight. A positive correlation was found to exist between the size of egg and the vigor of the chick by the West Virginia station. The amount of carbon dioxid given off during incubation appeared to be directly proportional to the vigor of the chick. Data secured at the Oklahoma station showed that on an average the chick was about 32 per cent lighter than the weight of the egg. Abnormally large or small eggs did not hatch as well as medium-sized ones.

Feeding chicks.—The West Virginia station found that an unbalanced ration fed to young chicks reduced the mature live weight of the females, increased the period before laying the first egg, decreased the fecundity, and reduced slightly the average weight of the egg. In experiments at the Wisconsin station chicks fed on white corn, middlings, and skim milk died in a few weeks; but if one egg a day for each 30 chicks was added, normal growth resulted. When eggs were used there appeared to be no necessity or advantage in adding green feed to the ration.

Protein supplements.—At the Nebraska station a ration with 15 per cent protein either as meat scrap or buttermilk gave good growth. Chicks on a nitrogen-free diet were found to transfer protein from one part of the body to another. In seven years' tests at the Missouri station animal concentrates proved superior to proteins of vegetable origin. Vegetable proteins were found by the Ohio station to be unsatisfactory for chicks unless supplemented with suitable mineral mixtures. An inexpensive mixture of bone or rock phosphate 60 parts, limestone 20 parts, and common salt 20 parts, used at the rate of 2 per cent of the total ration or 4 per cent of the dry mash, increased the value of vegetable protein rations for growth and egg production more than 40 per cent at a cost of only about 2 cents a year for each chick.

The North Carolina station found that when the ground velvet beans were fed alone or with the pods they were injurious. When fed to the extent of 45 per cent of the fattening ration or 28 per cent of the mash for growing chicks, they were also injurious. At the Indiana station, soy-bean meal proved fairly efficient as a substitute for animal proteins but not quite equal to them. It was much improved by adding steamed bone or still better dicalcic or acid phosphate to supply the mineral deficiency. As a result of three years' test, the Kentucky station concluded that the mash mixture should contain at least 20 per cent of meat scrap to secure maximum production without forcing the birds.

Tests at the Oklahoma station showed the most economical amount of tankage in the ration to be 25 per cent. The average weight of the eggs from hens receiving this amount was about 3 grams greater than that of eggs from hens receiving no tankage. The Kentucky station found that when sour skim milk was kept constantly before the birds, it was not necessary to feed a dry mash.

At the Idaho station it was found that this material could entirely replace meat scrap in the ration. At the Iowa station fresh buttermilk proved superior to other forms.

Grits and lime.—The Kentucky station found that a hen will retain the necessary quantity of grit, and that this is apparrently as effective as new grit. Limestone and rock phosphate served the same purpose and to the same extent as grit in the gizzard. The hens utilized the lime in calcium carbonate for the production of both eggshell and bone, but the lime in tricalcium phosphate was only utilized for growth of bones and not for eggshell formation. Calcium starvation was not the determining factor in the production of shell-less eggs.

Artificial lighting.—Best results were obtained at the Montana station by lighting in the morning from 5 o'clock to daylight. Hens that had morning light laid nine more eggs each during the year and gave extra returns of 54 cents each after paying the cost of the extra feed and lights. At the North Carolina station, keeping birds continuously under 14 hours of light each day caused overlaying and reduced egg production for the two succeeding years. Best results were obtained at the Utah station with morning light only, next best with morning and evening light. With evening illumination only the birds did not appear to be anxious for their feed and were restless and tired.

DAIRYING

Inheritance.—In color inheritance studies with Jersey cattle at the Kentucky station there were found to be three separate and distinct determiners controlling tongue, body, and switch color. Solid body color was dominant over broken body color, black tongue over white, and black switch over white. Yellow nose appeared to be recessive and gray color was dominant over all other coat colors. At the Maine station, in the crossing of Holsteins, Jerseys, Ayrshires, and Aberdeen-Angus, representing three levels in milk production, it was found that the crossing of a lower level with a higher tended to give a considerably higher production than the average for the lower members of the cross; but the reverse was true of the butterfat percentage, there being a decrease over that of even the lower members.

Milk production.—Analysis of a large number of milk records at the Maine station showed that sire and dam transmit milk production equally to the daughter and that 80 per cent of the variation in milk yield is due to controllable hereditary causes, the same applying to butterfat percentage.

Open Jersey cows slightly excelled pregnant ones in the production of milk and butterfat in studies at the Kentucky station. Two-year-olds produced 74 pounds of milk and 73 pounds of butterfat for every 100 pounds produced by mature 7-year-old cows. Three-year-olds produced 81 pounds, 4-year-olds 94 pounds, 5-year-olds 92 pounds, and 6-year-olds 96 pounds of butterfat compared with 100 pounds for 7-year-olds. No correlation was found between the production of milk and butterfat and the size and shape of the escutcheon and the amount or color of body secretions.

Leaving one-fourth of the milk normally produced in the udder at the last milking preceding the regular semiofficial test was found by the Pennsylvania station to slightly increase the yield of milk and butterfat in the following two-day test.

Studies at the Missouri station showed that, other conditions being approximately the same, the lower the environmental temperature the higher the percentage of fat in cows' milk, there being approximately 0.2 per cent increase in the fat for each decrease of 10° F. between 30° and 70°. No definite correlation was found between total solids and temperature. Sponging with cold water (50° F.) at two-hour intervals through the day tended to increase the percentage of fat and total fat in the night's milk. It was noted, however, that after a time this increase was not obtained, indicating that the animals may have become adjusted to the treatment. Under ordinary conditions of management of dairy cattle, independent of the season or character of the feed, there was a noticeable decline in the percentage of fat from the first to the second and sometimes to the third month of lactation, followed by a gradual increase, becoming more pronounced during the last month of lactation. The percentage of fat tended to be lowest in the summer months, then gradually rose and reached a peak during the winter months. When the different seasons of the year were accompanied with varying temperatures the influence of the season on the percentage of fat is greater than the advance of lactation. The average daily milk flow increased slightly through the second month and then gradually decreased until the end of lactation. If cows were milked immediately after coming into the barn after exercising, the difference in fat between the first and last portion drawn was from 3 or 4 to 7 or 8 per cent; but if the cows stood quietly for a while the difference might be as high as from 1 to 12 per cent. With Guernseys there was a gradual decrease in milk production after the first month of lactation, which had dropped about 50 per cent at the end of 12 months, but there was a slight increase when they went on pasture. Cows freshened in the fall produced the largest amount of milk for the year and the least when freshened in June, July, or August. A cow was found to reach her maximum production at 8 years of age.

Composition and properties of milk.—Lipase is not a normal constituent of milk, and its presence results in bitter milk, according to investigations by the Minnesota station. The depth of the cream layer on raw milk was found to be correlated directly with the viscosity of the milk.

That the energy value of milk solids is a constant but the fat may vary was shown by studies at the Illinois station.

Feed influenced the heat coagulation of milk materially in experiments at the Wisconsin station. Fresh milk from a cow on dry feed coagulated consistently at 246° F. in two or three minutes. With this same cow on pasture the milk did not coagulate at 246° in 30 minutes.

The methylene blue method for testing the bacterial content of milk, according to preliminary tests reported by the New Hampshire station, may serve as a satisfactory index of keeping quality and requires less apparatus, time, and technique than the plate method.

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It was found that a reduction time of three hours or less corresponded to a bacterial count of 500,000 or more per cubic centimeter; four to seven hours, 150,000; and eight hours or more, 25,000.

Nutrition and growth.—In studies on the protein requirements of dairy cows carried on by the Vermont station it was found sufficient to use a ration carrying a pound of digestible protein a day per 1,000 pounds of live weight for a low-milking cow and 1.5 to 2 pounds for a better producer. It was unnecessary for milk purposes to increase the digestible protein of the ration to 2.5 pounds per day per 1,000 pounds of live weight. Cows receiving for four and one-half years barely a pound of digestible protein per day per 1,000 pounds of live weight were not injured in respect to their physical condition, nor was the high-protein ration of 2.5 pounds in any respect injurious; but the cows receiving the high-protein ration tended to drop out earlier and to last a shorter time than those fed a medium (2 pounds) or a low (1.5 pounds) protein ration. Cows on a very low-protein ration after four and one-half years lost about 8 per cent of their live weight. Those on low and medium rations gained in body weight up to about 10 years of age, whereas cows fed a high-protein ration put on relatively little live weight and tended to lose slightly in weight after the seventh year. In milk production the high-protein ration cows averaged 3.5 per cent more product than the low and 2 per cent more than the medium, while the latter produced 2.5 per cent more than the low-protein ration cows. Short, alternate feeding tests were found to give results parallel to long-time tests, if carefully carried out and enough animals were used.

The Vermont station experiments also showed that the protein utilization varied profoundly with the ration changes in respect to the nutrient. In several instances, using the old-time 0.7 pound digestible protein maintenance allowance, recovery exceeded 100 per cent. Protein recovery was essentially identical for thin and rich milking cows. The results obtained suggest somewhat lower digestible protein needs than were set forth a generation ago. The total solids and fat content of the milk were unchanged by changes in rations, but to a slight extent their albuminoid content was changed, parallel to the protein content of the ration. Apparently, in the economics of the milk and butter production, a more nitrogenous ration is to be preferred. Cows bred to calve 12 to 14 months after calving tended to give, month by month, nine-tenths of the yield of the preceding month for nine months, then five-sixths of the yield of the preceding month to the end of the lactation period. Cows which had aborted tended to give, month by month, thirteen-fourteenths of the yield of the preceding month. Abortion was found to decrease the average milk flow one-fourth to one-fifth, and the total solids, fat, and albuminoid percentages increased about 0.2 per cent. If no material alteration occurred in the digestible nutrient intake, abrupt changes in digestible protein intake were not likely to be reflected in the milk yield.

Early stunting of calves did not appear to prevent later growth, according to observations at the Indiana station; but this later growth was made at a very high cost, because of the large amount of feed consumed during full feeding.

For medium producing cows, alfalfa hay was found by the Iowa station to supply sufficient calcium to take care of the requirements

for this element in the body. With a ration of timothy hay, however, a negative calcium balance prevailed. Alfalfa hay that was a year and a half old failed to produce a positive calcium balance, giving evidence that green plant tissues contain some substance that favorably affects calcium assimilation in the animal body.

Calf feeding.—Excellent results in feeding calves were obtained at the Arizona station with the use of a homemade substitute for milk, consisting of 2 parts finely ground corn meal, 1 part mill-run wheat bran, 3 parts wheat middlings, 2 parts oat groats, 1 part linseed-oil meal, 0.5 part blood meal, and 0.2 part ground bone meal, with 1 quart of milk a day for the first month. Feeding calves twice a day was found by the Idaho station to be fully as efficient as feeding three times a day and pasturing to be more economical than dry-lot feeding. At the Washington station calves were successfully raised on condensed buttermilk from the age of 3 weeks up to 4 to 6 months, making satisfactory gains of from 1.3 to 1.6 pounds per day. No trouble was experienced with scouring.

Milking machines.—Studies at the Texas station showed that with the same amount of care milk taken by hand was slightly lower in bacterial count than milk taken by machine. The yield of milk was not materially affected by either method if the cows were milked clean. It is considered good policy to strip the cows by hand after milking with the machine, although this may not be necessary with the best type of machine. One man with two single-unit machines was able to milk about twice as many cows in a given time as one man milking by hand. The economic advisability of the milking machine for any individual dairyman appears to be determined largely by the intelligence of his labor. The South Dakota station found no injury to the cows after several years' use of milking machines. Stripping the cows was an absolute necessity with all types of machines, and when this was taken into consideration there was not much saving over hand milking in small dairy herds. Under some conditions the bacterial count of the milk was found to be considerably increased, especially in the type of machine using double units, one set of cups being idle while the other was in use.

Home-grown feeds.—At the Wisconsin station a comparison of a home-grown feed, consisting of alfalfa hay, corn silage, and a concentrate mixture of corn and oats, with the same ration to which was added linseed and cottonseed meal, showed that the first maintained the yield of milk and butter fat as well as the ration containing the purchased linseed and cottonseed meal.

Silage for dairy cattle.—In a 120-day feeding test with dairy cows, at the Idaho station, sunflower silage produced 11.4 per cent more milk and 1.07 per cent less butterfat than corn silage. Figured on the basis of yield per acre, the difference in favor of the sunflower silage was considerable. Data secured at the Illinois station showed that sunflowers ensiled at a comparatively immature stage of development, when 20 to 25 per cent of the plants began to show rays of the blossoms, made more palatable and more digestible silage, and that such silage maintained milk production more nearly on the level with that produced with corn silage than when harvested at later stages of growth.

At the Oregon station there appeared to be little difference in the feeding value of sunflower, corn, and oat and vetch silages. At first

the sunflower silage was not readily eaten; but during the year the milk production of cows fed sunflower silage was the highest, as were the total nutrients per pound of milk and the total percentage of butterfat, oat and vetch silage being second in this respect and corn silage last. No flavor due to the feeds was detected in the butter from any of the lots. There seemed to be a slight tendency on the part of the sunflower silage to give a tallowy butter. The iodin values were: For sunflower silage butter, 29.317; corn silage butter, 26.965; and for oat and vetch silage butter, 26.247: indicating a larger content of olein in the butter made from milk of cows fed sunflower silage.

In comparative tests at the Montana station cows receiving corn and sunflower silage gave practically the same results as to milk and butterfat yield; but as the sunflowers produced about three times the tonnage of corn, they were the more economical feed. At the Pennsylvania station pure sunflower silage produced 86.4 per cent as much milk as good-quality corn silage. A silage made of half corn and half sunflowers produced 96.2 per cent. Corn silage was found to be superior to oat-and-pea silage for milk production. Silage from mature and medium mature corn proved to be better for milk production than that from immature corn. In a comparison of hay alone and hay with oat-and-pea silage for roughage with the same grain ration, the average daily milk production showed a decided advantage from feeding silage.

The Wyoming station found that sunflower silage was almost equivalent, pound for pound, to corn silage in the production of milk. Considering the cash cost of producing sunflower and corn silages on the basis of their acre yields, dairy cows produced both milk and butterfat more cheaply on sunflower silage, although the yield fell off slightly. Both sunflower and oat-and-pea silages were found to be about equal in value for wintering calves, but the oat-and-pea silage cost considerably more.

A comparison of corn silage with sorghum silage for milk production, at the South Carolina station, showed the latter to be 96 per cent as efficient as corn silage for producing milk, about 97 per cent as efficient for producing butterfat, and 88 per cent as efficient for maintaining body weight. Sorghum produced a heavier tonnage of silage than corn, which gave it a little advantage.

At the Minnesota station cows were fed moldy silage for four months without any injurious effects, nor was any injury noted in feeding cultures of molds in quantities far in excess of those that would be obtained in silage.

Protein supplements.—Cottonseed and linseed meal when fed in connection with alfalfa hay, corn silage, and corn and oats gave no increase in milk production at the Wisconsin station, indicating that protein supplements are not needed when a well-balanced ration is fed.

Velvet-bean meal fed to dairy cows apparently had no effect in changing the melting point of the butter fat in the milk, in tests made at the Florida station. Comparative tests, at the Mississippi station, of cottonseed meal and velvet-bean meal, both alone and mixed, showed that velvet bean and pod meal gave the largest returns and a mixture of cottonseed meal and velvet bean and pod meal the next largest. Three pounds of soaked velvet beans and pods appeared to be fully equal in feeding value to 2 pounds of cottonseed meal. In

feeding tests at the North Carolina station, velvet bean meal was not very palatable and the cows went off feed more quickly and produced a little less milk than on cottonseed meal. At the South Carolina station no bad effects were noted in the physical condition of cows receiving a large amount of velvet-bean meal, the results indicating that the meal maintained the body weight and milk flow quite as well as other feeds.

No effect on the flavor of the milk from feeding fish meal was noted at the Florida station, but the cows did not relish it, the maximum amount a cow would eat varying from 1 to 1¼ pounds per day.

Butter.—Butter made from ripened acid cream, at the Iowa station, scored higher at the beginning of the storage period than that made from sweet cream, and maintained this high score for 2 or 3 months, but at the end of 9 months' storage the sweet-cream butter was rated higher. In studies of the effect of heating and neutralizing cream, the best results were obtained when the cream was heated to 170° F. for 20 minutes. The keeping quality of butter was considerably improved by neutralizing the cream.

Tests at the Vermont station of storing butterfat at low temperatures showed that butter made from such stored fat was of better flavor than that of stored butter at the end of 7 and of 12 months.

The average cost of producing butterfat was found by the Arkansas station with three breeds—Holsteins, Jerseys, and Ayrshires—to be 42 cents per pound. The cost of producing 100 pounds of milk was $1.61 with Holsteins and $2.08 with Jerseys and Ayrshires.

The Wisconsin station found the fishy flavor of butter to be due largely to chemical decomposition of lecithin into trimethylamin, the factors favoring this condition being high acidity and high salt content in butter, combined with oxidation resulting from overworking in the presence of metallic utensils. Whey butter and creamery butter scored about the same, but the former kept longer.

Ice cream.—When the percentage of lactose in solution in the cream exceeded 10 per cent, the Indiana station found sandiness invariably occurring. Ice cream containing more than 12 per cent of milk solids-not-fat usually developed sandiness. Binders decreased sandiness but did not eliminate it. Commercial gelatin was found to be very variable in character and in its effect on the quality of the ice cream.

A comparison by the Nebraska station of mixtures containing from 6 to 20 per cent of butterfat, all other constituents and conditions being the same, showed that 18 and 20 per cent fat mixtures produced the best results from the standpoint of yield, consistency, and flavor. The lower percentages of fat yielded ice cream of good body but lacking somewhat in flavor.

The Missouri station found that increasing the butterfat in the cream mixture uniformly decreased the specific gravity and gradually increased the viscosity. The time required for the mixture to begin to freeze varied directly with the fat content, and the time required to whip the mixture was decreased, the net result being a decrease in the total time required to freeze mixtures with high fat contents. The most desirable flavor, body texture, richness, and appearance were obtained with a 10 and 12 per cent mixture. Varying the fat content had no effect on the freezing point. Increased increments of skim milk and of condensed and evaporated milk depressed the

freezing point. When the temperature remained constant, the body fat had no influence on the hardness. The higher the percentage of fat the longer the cream took to melt at 86° F. When scored after five days, that with 10 to 12 per cent of cream gave the best results. The overrun percentage increased up to 10 per cent of butterfat and then decreased. Skim-milk powder, condensed milk, and evaporated milk lowered the freezing point, but gelatin, gum tragacanth, etc., had no effect on it.

DISEASES OF LIVESTOCK

Infectious abortion.—Infectious abortion continued to be a prominent subject of investigation by a number of the experiment stations.

A vaccine prepared by the Kentucky station proved effective with mares, but of doubtful value with cows. In no case where mares were vaccinated as a prophylactic measure did the disease occur. Uninfected mares in infected herds were successfully immunized against the disease. The vaccine caused some stiffness of the neck, which disappeared in a few days. A hyperimmune serum was prepared but did not appear to have as much value as the vaccine.

Four years after inoculation with *Bacillus abortus* cows were found by the Missouri station still to be carriers of the infection and capable of infecting nonreacting pregnant cows through uterine discharges, afterbirths, etc. Nonreacting pregnant cows, allowed to mingle freely during their full gestation period with the inoculated cows, which had been bred a week or more after the younger animals, carried their calves to full term and did not develop a positive reaction. It appears that both cows and sows may become carriers and remain permanent reactors, as a rule, although a few may outgrow it. The transmission of immune bodies was found to occur in cattle as well as in swine, and complement-fixation bodies were taken by the calf through the milk.

As it is known that unbred heifers may become infected and established reactors, the Connecticut Storrs station made a study of other means of infection than from the bull, but did not succeed in bringing about infection by the administration of suspensions and cultures of *B. abortus* or of vaginal secretions through the mouth, other chances of infection being eliminated. Infection was repeatedly accomplished, however, by superficial injection into the urethra and by direct application to the inner surface of the vulva.

Animals are most apt to abort during the prenancy in which the initial infection is received, according to the Oregon station, and animals infected during their first pregnancy are more apt to abort than those infected during later ones. Animals from which the udder was surgically removed and then bred and confined with an infected cow became positive, but the reaction gradually diminished. The indications are that the habitat of the organism is in the udder and pregnant uterus only and is not in other portions of the animal's body. Accurate records of herds in the State show that the disease has not lost its virulence in seven years. There is found to be much more mastitis in infected than in abortion-free cows. Of 1,478 blood samples from various counties in western Oregon, 37.7 per cent were positive.

The average time required for abortion to result after infection was found by the Wisconsin station to be about 23 days in the sow and

about 58 days in the cow. It seems to be a more or less self-limiting disease in that a naturally acquired infection is usually followed by immunity, which will protect some sows for a long time; and the breeding efficiency of animals which have aborted is not necessarily impaired, although this depends somewhat on the individual.

A number of nonvirulent strains of *B. abortus* and many strains that decline in virulence after cultivation for several generations on an artificial medium are reported by the Michigan station. Attempts to produce the disease artificially or to secure immunization by means of cultures gave variable results at this station because of the variation in the virulence of the strains and the immunity to the disease of some of the animals tried. A simple plating method of detecting the organism in the milk has been worked out, which makes it possible to identify and isolate carriers. The investigations of this station indicate that the disease is transmitted by ingestion of infected material and not by the bull. Attempts to inoculate the udder through the teats gave negative results.

Studies by the Michigan station on the susceptibility of swine to bovine infectious abortion gave only negative results. At the Illinois station the disease was induced in swine by intravenous and subcutaneous injection of abortion bacilli as well as by feeding the bacilli from cases of swine abortion. In all cases examined by the Missouri station pigs from positive sows were negative before nursing and positive afterwards. See also page 119.

Hog cholera.—Exposure experiments were carried on at the Indiana station with the following results: In two sets of pens in the field separated 4 and 8 feet apart, respectfully, one pen in each set containing cholera pigs and the other healthy nonimmune pigs, visible symptoms of cholera were manifest in the controls on the sixteenth and nineteenth day, respectively. In pens in a small house separated only by cheesecloth, one containing cholera pigs and the other healthy animals, the latter were well on the thirty-third day when their susceptibility was proved by inoculation. Healthy pigs placed in a field pen three and four days after sick and dead cholera pigs were removed from it were well on the thirtieth day, and their susceptibility was then proved. In a building having a concrete floor, 6 lots of 4 pigs each were placed in pens which were heavily bedded with straw and sprinkled with cholera blood 1 to 6 days before turning in the pigs. One or more pigs showed visible signs of cholera on the eighth day. Repeating this with outdoor pens, putting the pigs in 4, 5, and 6 days after infecting the pens, all the pigs were well on the fourteenth day. Feces and urine collected from cholera pigs killed on the fifth day after inoculation and showing visible symptoms did not produce cholera when fed to susceptible pigs. Of 2 lots of susceptible pigs fed with feces from a pig killed on the seventh day after inoculation, 1 pig developed the disease, while 2 other lots fed urine from the same pig remained well. Post-mortem examinations showed that hemorrhagic lesions occurred as early as the fifth day and intestinal ulcers as early as the ninth day after inoculation.

At the Minnesota station a test of the length of time that serum-virus treated pigs act as carriers and disseminators of cholera showed that susceptible pigs placed with such treated pigs between the fourteenth and twenty-first day after treatment contracted cholera, but after the twenty-first day no exposed pig contracted the disease.

Studies on the natural immunity of suckling pigs carried on at the Maryland station showed that pigs inoculated at birth were immune as long as they were nursing immune mothers, but developed the disease when they ceased to nurse.

The North Dakota station found that when the serum-virus was precipitated with sodium tungstate and sulphuric acid, allowed to stand and filtered through ordinary filter paper, a protein-free nonvirulent filtrate was obtained; but the precipitate was virulent. Similar tests with swamp-fever virus showed its virulence to be completely destroyed by the chemicals involved in the precipitation.

Other swine diseases.—Losses from diarrhea in shoats, at the Kentucky station, were almost completely overcome by improved sanitation, modification in the administration of serum and virus for permanent immunization against hog cholera, and the use of a bacterin made from microorganisms isolated from infected individuals. In studies of dysentery in swine, the Indiana station found the virus to be present in the stomach and colon, but not in the lungs, spleen, liver, kidneys, or heart. Posterior paralysis of swine was found by the Minnesota station to be due to a deficiency of calcium in the diet.

Hemorrhagic septicemia.—In all attempts by the North Dakota station to produce this disease in hogs by feeding the organism even under conditions of gross neglect of hygiene and sanitation, with improper and deficient food, no method of inoculation was found which would regularly induce an infection in hogs. Of 12 cholera-infected pigs, 6 showed the presence of the bipolaris bacillus, but the harboring of this organism in the lungs did not of itself appear to alter the course of an infection of hog cholera. The investigations of the station indicated that there are specific types of the organism attacking different animals, which may be designated as the bovine-swine, ovine, avian, and rabbit-cavia types.

Vaccine made from attenuated living organisms was found by the Oregon station to control the disease within a few days. The station recommends the vaccination of all young animals, both sheep and cattle, each year as a preventive.

The Nebraska station found that, however marked the protective qualities of a serum may be, the passive immunity conferred by it is of a rapidly evanescent character and completely vanishes within a week. Commercial sera were found to vary widely in their power to secure immunity, but in the best the period of protection was short, being only from four to seven days as a rule. Animals treated with serum and virulent cultures did not become actively immune and succumbed to subsequent injections of the virus.

A comparison of the value of live and dead septicemia organisms for vaccination at the Colorado station showed that the live organisms give the greater immunity.

Hemorrhagic disease of cattle.—Station work on this disease is noted on page 120.

Anthrax.—The Louisiana station found that anthrax was transmitted from infected guinea pigs to experimental animals by *Tabanus quinquevittatus*, *T. lineola*, *T. costatus*, and *T. fuscicostatus*, the highest percentage of infection, about 50 per cent, being obtained with the first-mentioned species when the flies were allowed to feed on sick and then on healthy pigs. The percentage of infection was highest in June and July and none was produced in September and October.

Several species of flies gave negative results. About two-thirds of the infested pigs showed no external symptoms, but died with internal symptoms within 48 hours after exposure to the infected flies. The organisms were still virulent in cultures in sterile and unsterile water after 12 years, in milk cultures after 10 years, and in dog feces after 9 years. Commercial vaccines 5 years old showed no deterioration. Fish in inoculated solutions were killed by the disease, and the dead bodies were found to carry the organism. The Oregon station demonstrated that the anthrax organisms may be recovered from the ear, thus making it unnecessary to open a carcass in order to secure material for examination.

Tuberculosis.—Particularly notable work on tuberculosis was reported during the year by the California station on the longevity of the tubercle bacillus, and by the Minnesota station on the importance of secondary or incidental reactions of early tuberculin tests from the standpoint of diagnosis. For further review of station work on this subject, see page 119.

Swamp fever.—The North Dakota, Texas, and Wyoming stations reported especially notable work on this disease during the year. For a review of the subject, see page 120.

Necrobacillosis.—The Wyoming station continued its work on this disease. This and other station work on this disease is noted on page 120.

Texas fever.—Tests made at the Texas station showed that Brahman cattle may be artificially inoculated with Texas fever and that they are also capable of carrying the infection for a period of at least 83 days.

Mastitis.—From a study at the Oregon station of the udder flora of animals showing a history of infectious mastitis, it appeared that most of the animals examined harbored an organism identical with streptococcus mastitis indefinitely after recovery from the disease. A high percentage of garget was found in animals that reacted to the complement-fixation test for abortion. One form of matitis in cows was found by the Maryland station to be a water-borne disease and apt to be carried on milking machines. By ceasing to use the machines, the disease was eliminated. The causal organism was found to be *Pseudomonas pyocyaneus*, which is not usually pathogenic.

Infectious diarrhea of cattle.—An outbreak of this disease studied by the Louisiana station was found to be apparently caused by a protozoa of the Prowazekia group. A commercial preparation of sulphocarbolate fed for two or three days during the earliest stages seemed to effect a cure in many cases, but it was not found to be a preventive. The disease is believed to be water borne.

Botulism.—Animals at the Kentucky station affected with what was diagnosed as forage poisoning recovered when large doses of magnesium sulphate were administered. In a study of an outbreak of a disease in chickens and ducks with the clinical symptoms of botulism at the Illinois station, an anaerobic, nonmotile, Gram-positive, spore-forming organism was found, which when cultured and fed to guinea pigs induced symptoms resembling botulism, but which were not controlled by A and B botulinus antitoxin, suggesting the existence of a third type, C.

Sheep and goat parasites.—Investigations on the stomach worms of sheep at the Connecticut Storrs station showed that the parasites

not only suck the blood but also introduce a toxin. Nicotin sulphate in suitable doses, with previous dosage with Epsom salts, proved a very efficient treatment. Treatment with copper sulphate alone was not satisfactory, although the Texas station used it with good results with goats and less satisfactory results with sheep. The Oklahoma station found that the larvæ hatch out on the ground and molt in a few days, after which they reach the infectious stage and migrate to blades of grass wet with dew or rain, especially at night or during diffused light. When eaten by grazing animals they reach maturity about three weeks after reaching the stomach. The larval worms may live for several months and withstand adverse weather conditions—freezing, thawing, and drying—without much injury. The station recommends copper sulphate with tobacco as a remedy.

In life-history studies of the lungworms of sheep, the Oklahoma station found the course of migration of the larval worms to be from the alimentary canal to the lungs by way of the blood and lymph vessels. The larvæ remain for a time in the lymph glands and then pass into the blood stream, by which they are carried to the lungs. Here they penetrate the capillaries, which they break down, and enter the air spaces. They later work their way to the larger air spaces, where they grow to maturity. The larvæ were fed to lambs for several days, and 20 days later the worms were found distributed through the blood, lungs, lymph, liver, and other organs. Negative results were obtained by subcutaneous inoculation.

Poultry diseases.—Investigations at the Kansas station on bacillary white diarrhea showed that the hatchability of eggs from reacting hens was from 12 to 20 per cent less than from the nonreactors. The albumen of the eggs from infected hens caused agglutination in affected birds. This material can, therefore, serve to test the reaction of the hens.

The Oregon station found that in cases of coccidiosis, treatment with hydrochloric acid added to the drinking water in the proportion of 1 part to 500 gave good results. Attempts to transmit the disease by feeding the intestines of infected fowls to healthy ones were unsucessful.

Studies at the Colorado station of the sod disease of chickens, so called because it apparently does not occur on irrigated land or on dry land where the sod has been broken up and cultivated, did not definitely show its cause. It appeared to be infectious, but attempts to isolate the causal organisms gave negative results. The disease starts as blisters between the toes, with the formation of scabs, the feet become swollen and tender, and the toes may drop off. The symptoms sometimes appear on the head also. The mortality may even run as high as 90 per cent, but is usually not over 20 per cent. It is most prevalent in summer. It usually affects small chicks worse than adults. Dipping the feet and bills in kerosene was found to be an effective treatment.

Life-history studies at the Kansas station of the fowl nematode (*Ascaridia perspicillum*) showed that the eggs when passed by the fowl developed to the infective stage in moist ground in about two weeks during the spring, summer, and autumn. When these eggs were swallowed by young chicks, they hatched in the small intestine and developed to maturity in four to six weeks. Four generations of worms may develop from March to December. In the presence of

ample moisture, normal development of the embryos was retarded in the egg when the temperature reached and was maintained at from 40° to 44° C. for a few hours, but most of such eggs reached an infective stage. With temperatures of from 45° to 49° very few reached this stage. The eggs can withstand freezing. Although larvæ of the large roundworm migrate from the intestines through the tissues of the host to the lungs, from which they are returned to the stomach, the chicken roundworm seldom migrates thus. The Minnesota station found that a mixture of 20 parts of oil of turpentine with 1 part of chloroform, introduced into the crop of the fowl with a catheter, was from 80 to 100 per cent effective as treatment. At the Oklahoma station infection was produced by feeding eggs to chicks. The larval worms were found to migrate in the chick's body, but only a few reached the lungs. Feeding larval or longer worms to chicks did not produce infection. Treatment with 1 per cent copper sulphate solution with tobacco eliminated from 60 to 70 per cent of the worms.

Hookworms.—The Kansas station found that eggs of the human hookworm will pass through the digestive tract of the pig uninjured and will develop afterwards, but after passing through the chicken only about 10 per cent will develop, owing to the action of the gizzard.

Poisonous plants.—Studies of plants poisonous to livestock and their effects, in large part continuing previous work, were reported by a number of stations, notably by the Colorado station on the whorled milkweed (*Asclepias galioides*); the Indiana station on white snakeroot (*Eupatorium urticæfolium*); Montana station on eradication of loco (*Astragalus blankenshipii*); and Nevada station on seaside crowfoot (*Halerpestis cymbalaria*), western goldenrod (*Solidago spectabilis*), saltbushes (*Atriplex* spp.), mountain laurel (*Kalmia microphylla*), rabbit brush (*Tetradymia glabrata*), larkspur (*Delphinium* spp.), and clover sage (*Artemisia spinescens*). See also pages 116–119

RURAL ECONOMICS

Why some farms pay.—The Wisconsin station, in a study of why some farms pay while others with similar soils and topography and the same seasonal conditions and markets do not, found that large farms have generally been heavier losers than small ones. The two outstanding ways in which the farms that have made money differed from the others were the increased number of sources of income (diversification) and the greater production of the dairy herd. In one area investigated the average production of milk per cow was 5,600 pounds, which is not a paying proposition. As the average production per cow increased from an average of 4,625 pounds in the lowest herd to 8,138 pounds per cow in the best herd, the average farm income increased from $476 to $1,205, and the cost of milk produced in this case decreased $1.19 per 100 pounds.

Farm management.—Studies on 181 farms by the the Idaho station showed that chief factors contributing to the success of most successful farms were (1) the production of high crops yields, (2) the selection of the most profitable crops to grow, (3) marketing the crops early in the season before prices had fallen materially, and (4) keeping expenses at a low level without interfering with the production of high crop yields.

Livestock versus grain farming.—In a comparison of livestock and grain farming at the Ohio station, the average yields were distinctly less in grain farming than in livestock farming. The Kansas station found that, as a rule, poultry gave good returns on labor, amounting to from 40 to 90 cents per hen.

Cost of production.—In studies at the Missouri station it was found that the average cost of production in the State in 1921 was $2.26 a bushel for wheat, 63 cents for oats, and 62 cents for corn. As the yield increased the cost per acre increased; but the cost per bushel decreased until the optimum yield was reached, when it again increased.

The Washington station found that the cost of milk production varied on individual farms in that State from $1.81 to $4.56 per 100 pounds. In 1920 a price of $3.40 per 100 pounds would have covered the cost of producing 90 per cent of the total milk produced by the herds studied. The basic requirements for producing 100 pounds of milk were found to be 17.7 pounds of grain, 38.2 pounds of hay, 47.1 pounds of succulents, 3.1 days' pasture, and 2.3 hours of man labor. The studies indicated that the cost of producing milk may be materially reduced by the use of better stock, better feeding, and better labor management.

On the basis of data from 200 farms, the Illinois station found that 1.38 hours of man labor and 2.02 of horse labor were required per ton of silage. By efficient management, 22 of the farms put up silage with an expenditure of less than 1 hour of man labor and 1½ hours of horse labor per ton.

In a study of the cost of producing wheat, oats, and corn at the Kansas station, the use of tractors was found to give a higher cost per unit of yield. The Indiana station found horse power more economical than tractors.

Marketing potatoes.—Investigations at the North Dakota station showed that farmers do not exercise sufficient care in sorting and grading their potatoes to meet the requirements of the markets. Freight haul on North Dakota potatoes was found to be over 40 per cent of the gross returns of the crop.

TECHNOLOGY

Flour and bread.—The viscosimeter was found by the Minnesota station to be an accurate and rapid means of measuring slight changes in the colloidal properties of flour. Suspensions of flour in water were found to be extremely labile systems, affected by many factors which influence the viscosity of emulsion colloids. Maximum viscosity, due to action of acids on flour, was obtained with an acidity of pH 3, regardless of the nature of the acid. Maximum viscosity with alkalis occurred at approximately pH 11. Glutenin was the protein mainly responsible for the inhibitional power of flour and gluten. The rate of maltose production in dough was very regular at any given temperature. As the time of fermentation increased, the acidity of the dough likewise increased, causing a considerable increase in the rate of maltose production. The addition of malt preparations to doughs increased the volume of the resulting breads and the baking strength of the flour.

Shrinkage in the curing of meats.—Studies at the Missouri station showed that in hams there was 3.5 per cent shrinkage with old hogs and 12.5 per cent with young ones, with little difference between hogs of the same weight. In all cases, the greater shrinkage was with young animals. The dressing percentage on lean steers was 52 and on fat steers 62, the shrinkage in the cooler from lean steers being 1.2 per cent and from fat steers 1.6 per cent.

Sugar and sirup.—In the clarification of cane juice, the Louisiana station found that little advantage is to be gained by artificially changing the hydrogen-ion concentration of natural juice by the addition of acid or alkali after simple clarification with an inert medium, such as diatomaceous earth. Any adjustment of hydrogen-ion concentration may better be made during clarification. A study of the precipitate which forms in greater or lesser amount in the sirup resulting from concentration of cane juice, regardless of what method of clarification is employed, showed that a large part of the inorganic constituents of the precipitate is derived from soil clinging to the cane when it is received at the mill. No way of forcing this precipitate to come out in the ordinary course of clarification has been found.

In studies of sugar deterioration, the Louisiana station found that the extracts from some of the species of mold fungi occurring in sugar invert sucrose at densities beyond the maximum to which mold itself is active, indicating the possibility of sugar deterioration occurring in the absence of living organisms. Of 30 species of mold studied for their inverting power on cane sugar, *Aspergillus repens*, *A. niger*, and blue aspergillus were found to be most active. It was noted that in the presence of toluene no inversion from mold spores took place. Gum levan, produced by bacteria in sucrose solutions, was found to be formed directly from sucrose and not from the product of its inversion. Its formation was decreased by the presence of invertase in proportion to the activity of this substance. Formation was greatest when the hydrogen-ion concentration was least favorable to inversion. The reaction of limed cane juice was more suitable for gum levan formation than that of either raw or sulphured juice. Two bacilli, *Bacillus mesentericus vulgatus* and *B. furcus*, were found to have, to a slight degree, the ability to form gum levan, and this was increased when the organisms were grown in a sucrose solution. It was shown that the manufacture of a sugar conforming to the "factor of safety" depends upon graining it from a sirup of such purity that the surrounding medium of molasses exceeds in density the maximum at which mold fungi can develop. Molasses in the form of a film deteriorates when apparently insusceptible to such changes in deep layers. The size of grain has considerable influence upon moisture absorption, the latter varying inversely with the size, and the largest amount is absorbed the first day. The smaller grains are much more hygroscopic than the larger ones. The presence of small amounts of invert sugars and the merest traces of the decomposition products of lime upon the reducing sugars greatly increase the affinity of sugar for moisture.

In attempts to make sirup from sweet corn stalks, the Minnesota station found it possible to secure by the open kettle process about 20 gallons of excellent sirup from the stalks cut from 1 acre.

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EXPERIMENT STATION WORK ON THE FAT-SOLUBLE VITAMINS

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REVIEW OF EARLIER WORK

In the 10 years which have elapsed since the announcement almost simultaneously by the Connecticut (*1*)[1] and the Wisconsin (*2*) stations of the discovery of the presence in certain natural food materials of a fat-soluble vitamin essential to normal growth and well-being, many investigations have been conducted at various experiment stations and elsewhere, showing with ever-increasing significance the important part which the fat-soluble vitamin, vitamin A, plays in normal nutrition.

Occurrence and properties.—Following the discovery of this vitamin much information was contributed from both the Connecticut and Wisconsin stations which showed its wide occurrence in animal and vegetable materials and threw light on its physical, chemical, and physiological properties. Significant among the early contributions was the observation first reported by Osborne and Mendel (*3*) of the relation between lack of vitamin A and the development in experimental rats of a characteristic form of ophthalmia. That this was not characteristic of rats alone was shown by experiments at the Iowa station (*4*) with rabbits and at the Wisconsin station (*5*) with dogs. Evidence of more extended physiological disturbances, including general cutaneous malnutrition and a tendency toward respiratory infection, was contributed from the Wisconsin station (*6*).

Steenbock, of the Wisconsin station, developed his interesting hypothesis of a correlation between the occurrence of vitamin A and lipochrome pigment in many materials. Although this theory has been refuted by Palmer and his associates at the Minnesota station, the list of materials rich in vitamin A and in lipochrome pigment is sufficiently long and the exceptions are so few as to point to some chemical or biological relationship.

Storage.—The ability of the animal body to store fat-soluble vitamin was suggested in the earliest work of Osborne and Mendel, but failure on the part of many investigators to appreciate the effect of such storage in experimental animals has rendered valueless much of the earlier work on its quantitative occurrence.

Relation to reproduction.—It was soon discovered that this vitamin is necessary for reproduction and successful lactation, and it was realized that the experimental work should be carried through several generations. The relation of fat-soluble vitamin to reproduction has, however, been somewhat complicated by the studies of Evans and Bishop at the University of California. Briefly stated, these investigators have demonstrated two forms of sterility in rats apparently resulting from lack of unidentified constituents of the diet. One form

[1] Italic numbers in parentheses refer to References, p. 86.

(*7*) occurs on diets lacking in vitamin A in the sense in which the term is ordinarily used. This type of sterility has been definitely traced to the impairment of germ cell vigor by selective ovarian disorder. The other (*8*) has been demonstrated to occur to a considerable extent in the first generation and wholly in the second on diets consisting of purified protein, fat, and carbohydrate, with adequate amounts of vitamins A and B. This form of sterility is characterized by placental rather than ovarian disorder, and can be prevented or cured by the addition to the diet of certain foodstuffs such as fresh green lettuce leaves, alfalfa, wheat germ, and butterfat (the latter if fed in large amounts). It will be noted that all these substances contain vitamin A, but cod liver oil, which is rich in this vitamin, is ineffective in curing or preventing this form of reproductive disorder. Apparently this new vitamin, vitamin X, is closely related to but not indentical with vitamin A.

Relation to mineral metabolism.—In 1920 the Wisconsin station (*9*) reported the results of some preliminary experiments which suggested the presence in green plant tissues of a factor influencing calcium metabolism. Milking goats were brought to a negative calcium balance on a ration of air-dried grains and air-dried roughage, but when the latter was replaced by fresh material equivalent in dry matter and calcium content the negative balance was greatly reduced. The suggestion was made at this time that "under the extra strain of rapid growth or milk production not enough calcium can be assimilated for the liberal uses made of this element unless there is present an abundance of calcium in the diet, as well as an abundance of this something that assists calcium assimilation. Possibly we are dealing with the antirachitic vitamin assumed as the fourth accessory factor."

Further evidence of the correctness of this hypothesis was furnished by a more elaborately planned experiment (*10*) in which it was shown that the negative calcium balances in milking goats on dry rations could be greatly reduced by fresh green material (oats) or by the same material freshly dried or made into hay in the diffused light of an attic. Orange juice and cabbage (rich in vitamin C) and butter (rich in vitamin A) were ineffective, while cod liver oil in doses of from 5 to 10 cubic centimeters daily consistently changed the negative balance to positive. These results pointed to the identity of the vitamin assisting calcium metabolism with the antirachitic vitamin now being differentiated from vitamin A, and also emphasized the interrelationship between this type of fat-soluble vitamin and mineral metabolism.

Meaning of term "fat-soluble vitamins."—Thus the conception of the fat-soluble vitamin has enlarged to include tentatively a factor essential to growth and reproduction and to resistance to infection of various kinds, a factor intimately concerned in the metabolism of calcium and phosphorus and thus in the prevention of rickets, and possibly a factor the lack of which is responsible for sterility of a certain type. This has resulted in a confusion of terms which makes the literature on the subject somewhat difficult to interpret. The term "fat-soluble vitamin" or "vitamins" is generally used to designate the group as a whole. Vitamin A is sometimes used in the collective sense and sometimes only as representing the growth-promoting or antixerophthalmic factor. The term antirachitic vitamin refers specifically to the factor associated with the metabolism of calcium

and phosphorus, and the factor associated with reproductive disorders not due to lack of vitamin A is known as vitamin X.

WORK IN 1922

Vitamin A requirements of different kinds of animals.—Hesitancy in applying to other animals the conclusions drawn from the results obtained with the white rat, used so extensively in nutrition experiments on account of its rapid growth and small food requirements, has been largely overcome through the similarity in results obtained in vitamin work with animals of different species.

In experiments at the Iowa station (*11*) it was found that on a diet deficient but not absolutely lacking in vitamin A (white corn 55, linseed meal 22, ground oats 15, tankage 15, and salt mixture 3 parts), rabbits varying in age from 3 to 8 weeks developed ophthalmia in from 2 to 8 weeks, and died in from 2 to 3 months. On the same diet young rats grew at less than the normal rate to maturity and reproduced, but the young were not suckled and died in a few hours. A sow fed the same ration during the gestation and suckling period farrowed four unthrifty pigs, one of which died and the others grew very slowly until the ration was supplemented with butterfat. In preliminary experiments with chickens on this diet, soreness of the eyes developed in one case. These results indicate the need of vitamin A in varying amounts by all of the animals tested. That an amount sufficient for ordinary purposes may not be enough to meet the extra demands of lactation has also been demonstrated in an extension of the work with rabbits.

Evidence that the antixerophthalmic and antirachitic vitamins are not the same is furnished in experiments at the Wisconsin station on dogs (*12*). It was found impossible to prevent rickets in rapidly growing dogs with as much as 60 grams of green alfalfa or 42 cubic centimeters of orange juice as the sole source of fat-soluble vitamin, although these amounts were much in excess of those required to prevent ophthalmia. In these experiments it was shown, however, that the antirachitic vitamin resembles vitamin A in its resistance to saponification.

Chickens.—In investigations at the Wisconsin station (*13*) it was found that leg weakness developing in chickens on a synthetic diet or on a simple diet of white corn and skim milk, with a small amount of calcium carbonate and common salt, can be prevented by the use of a liberal amount of cod liver oil. When the oil was omitted from the ration the chickens died in from four to six weeks with gross symptoms of leg weakness, thus indicating that the antirachitic factor was the one chiefly involved.

The Wisconsin station (*14*) has also shown that a ration of white corn, middlings, and skim milk, previously found to be inadequate for normal growth, may be made adequate by the addition of one egg per day to the ration of 30 chicks. Growth on yellow corn, middlings, and skim milk was also improved by this addition. Furthermore, egg can be used to replace milk when the latter is not available and apparently gives as good results as a supplement of green feed. It would seem that the effect of the egg is due, in considerable measure at least, to the high content of fat-soluble vitamin in the yolk. In this connection it should be noted that egg yolk has recently

been reported to be high in antirachitic vitamin (*15*, *16*). At the Wisconsin station it has been demonstrated (*17*) that the hatchability of eggs can be increase by the addition to the ration of laying hens of substances rich in vitamin A. The average hatch was higher on yellow corn and casein than on white corn and casein, and was increased in both cases by the addition of skim milk, and still more by pork liver. The low hatchability on the deficient rations was more pronounced during the latter part of the hatching season. This indicates a gradually diminishing store of vitamin A in the body of the hens, and points to the advisability of furnishing additional sources of vitamin A to hens in the late winter or early spring.

The results obtained at the West Virginia station (*18*) in a two-year study of the effect of confinement and green feeds on the number, fertility, and hatchability of eggs point indirectly to a favorable influence of vitamin A on the fertility and hatchability, but not on the number of eggs produced.

The work reported by the various stations would thus seem to indicate that the chick requires fat-soluble vitamin for growth, for successful reproduction, and for the prevention of rickets or leg weakness. Other problems of interest, some of which are under active investigation, are the most economical sources of fat-soluble vitamin for growing chickens and laying hens, a further study of the relation of feed to the hatchability of eggs to determine whether vitamin A or the vitamin X of Evans and Bishop is alone involved, and an application to chickens of the results obtained in experimental rickets in rats to determine whether lack of antirachitic vitamin can be compensated by more favorable proportions of calcium and phosphorus or by light. From the standpoint of human nutrition the selection of rations for laying hens to increase as far as possible the content of fat-soluble vitamin in the egg is of great importance.

Swine.—The problem of meeting the fat-soluble vitamin requirement of swine has been considered in studies of the comparative feeding value of yellow and white corn. The higher content of vitamin A in yellow corn, as demonstrated at the Wisconsin station (*19*), makes it especially desirable to use yellow corn in preference to white at the time of greatest need for vitamin A, or to supplement the white corn at such a time with materials rich in vitamin A.

At the Illinois station (*20*) it was found that continued subsistence on a white corn and tankage ration gradually undermined the reproductive powers of breeding sows. One sow restricted to such a ration produced litters of dead pigs in the third and fourth gestation periods. In similar feeding tests conducted on young pigs from 50 to 70 pounds in weight at the beginning of the experiment, the gains in weight and general condition of the animals receiving yellow corn were somewhat better than of those receiving white corn; and it was concluded that growing pigs require vitamin A, but that the requirement is of a low order compared with that of the reproduction period.

Experiments at the Iowa station (*21*) also indicate that for swine the difference between yellow and white corn is not so important during the later growing and fattening period as during the breeding and early growing period; that is, for the normal growth of young pigs and for successful reproduction white corn must be supplemented with good pasture or with feeds furnishing vitamin A, while for fat-

ening pigs in dry lot white corn appears to be about as efficient as yellow. Similar conclusions have been reached at the Wisconsin station (*22*), where it was found that there was a more striking difference in the rate of gain of pigs fed yellow corn and skim milk as compared with those fed white corn and skim milk in the young animals than in those which were fairly well grown at the beginning of the experiment. This was attributed to the fact that these animals had been raised on excellent rations, with good pasture, and had evidently stored sufficient vitamin A to carry them through the fattening period. Most of the young animals on the white corn ration developed rickets, as indicated by the gross symptoms and the low content of inorganic phosphorus in the blood, and also by the fact that 10 cubic centimeters of cod liver oil daily never failed to correct the deficiency. Chopped alfalfa to the extent of 5 per cent of the ration has been found by this station to be adequate to prevent rickets or paralysis in young pigs fed white corn and skim milk. It is thought probable that chopped clover or soy-bean hay would serve the same purpose equally well.

The Ohio station (*23*) has also reported that lameness, rickets, or partial paralysis in hogs can be prevented by feeding bright leafy alfalfa hay to the extent of from 3 to 5 per cent of the ration or by the addition of a mineral mixture containing steamed bone meal, ground limestone, acid phosphate, and common salt.

Dairy cattle, with special reference to mineral metabolism.—The successful feeding of dairy cattle depends largely upon the selection of such food materials as shall make for quality and quantity of milk production with as small a drain as possible upon the body reserves, particularly of calcium and phosphorus. Evidence obtained with small laboratory animals that lactation involves an increased requirement of fat-soluble vitamin and that the content of vitamin A in the milk depends upon the richness in this vitamin of the food of the lactating animal has been confirmed in an investigation at the Minnesota station (*24*) of the content of vitamins A and B in the milk of cows on rations rich and poor in these vitamins, as demonstrated by experiments with rats.

These investigations demonstrated conclusively that the content of vitamins A and B in cow's milk depends ultimately upon their presence in the ration, although storage of vitamin A in the body tissues enables the cow to maintain the level of vitamin A in the milk for some time after the supply in the feed has been exhausted. That a vitamin-rich milk is not necessarily correlated with access to pasturage was shown by the excellent results obtained with the milk from cows stall-fed on a ration of grains supplemented with alfalfa and corn silage. Such a ration would tend to furnish a more even vitamin content than a grain ration of low vitamin content supplemented by pasturage under varying climatic conditions. The drying of the pasture during a portion of the experimental period was reflected in a lowering of the vitamin content of the milk, particularly with respect to vitamin B.

In similar feeding experiments at the Ohio station (*25*) it was found that rats receiving, in addition to a basal diet free from vitamins, milk produced by cows on pasture grew faster than those receiving an equal amount of milk from cows on a dry feed. It was

suggested that the vitamins of the hay are destroyed by excessive sunlight and drying and possibly by overmaturity of the grass when cut for hay.

It is evident that the antirachitic factor is an important one to be considered in the feeding of dairy cattle if the results of the extensive investigations of the past two or three years on experimental rickets in rats are applicable to the larger animals. These have shown that the presence of the antirachitic vitamin in the food enables the animal to utilize calcium and phosphorus more efficiently.

It has long been known that lactation results in a considerable depletion of the reserve supplies of calcium, and that during this period it is very difficult if not impossible to maintain a positive calcium balance. Circumstances in which this depletion of calcium plays an important rôle are summarized by Forbes and others as follows (*26*):

There is greater difficulty in getting a cow with calf after heavy and prolonged lactation than if bred comparatively soon after calving; cows bred too young tend strongly to remain permanently small; occasionally a cow will fail, unaccountably, after calving to approach her normal milk production; cows calving while in especially thin condition, or calving without having had an adequate dry resting period, are apt to begin lactation at less than the normal rate, or, after a brief term of production, to fail abruptly; and performance tests of milch cows, under conditions of forced production, have resulted in the loss of breeding capacity of so many superior cows as to occasion frequent comment and discussion among dairy cattle breeders.

These observations led to a series of studies at the Ohio station on the mineral and nitrogen metabolism of milch cows. In the first of these studies (*27*) it was shown that during the period of liberal milk production it was impossible to maintain a positive calcium balance on rations of hay, grain, and silage. The phosphorus balance was also negative in nearly all cases. The losses were greater on timothy than on clover hay, but the differences were not proportional to the difference in the calcium content of the two roughages. In the second series of studies (*28*) it was demonstrated that on the addition to the ration of large amounts of calcium carbonate, steamed bone flour, and sodium chlorid, the calcium balance remained negative while the phosphorus became positive; and in the third that the more soluble calcium compounds, calcium lactate and chlorid, and precipitated bone phosphate were utilized no better than the less soluble calcium carbonate.

In the fourth series of studies (*26, 29*) the scope of the investigation was extended still further to include the whole of the productive life of the cow. In 7 of the 18 balance experiments included in the series the cows were entirely dry, in 4 were giving less than 10 pounds, and in the remaining 7 from 37.87 to 61.36 pounds of milk per day. The ration consisted of corn meal, 13 parts; cottonseed meal, linseed meal, and wheat bran, 1 part each; alfalfa hay ad libitum; and common salt in the proportion of 0.007 that of the grain. The mineral supplement consisted of equal parts of precipitated bone phosphate and precipitated calcium carbonate. As in the previous trials, the cows giving a liberal amount of milk had negative calcium balances. In contrast with this the dry cows and those giving a very small amount of milk had positive calcium balances. The phosphorus balances, with one exception, ran parallel with the calcium.

The general conclusion drawn from this series of studies was that a negative calcium balance during lactation, at least on winter rations, is practically inevitable, and that consequently it is necessary for dairy cattle to have a dry resting period during which the feeding should be sufficiently liberal for the building up of extensive reserves for the following period of lactation.

That a positive calcium balance can be obtained in lactating animals even on winter rations has been demonstrated at the Wisconsin station. Previous work with goats has been mentioned in which it was shown that a negative calcium balance may be reduced or even made positive by supplementing the dry feed with such substances as green alfalfa and cod liver oil. The negative results with fresh cabbage as a supplement have been confirmed (*30*), and similar negative results have been obtained with yellow carrots; but an alcoholic extract of alfalfa has been shown to be effective in bringing about a positive balance.

In a continuation of this investigation (*31*) an attempt was made to determime the comparative efficiency of dry and green alfalfa in maintaining calcium and phosphorus equilibrium in milking cows. It was anticipated that negative calcium balances would be obtained with dry alfalfa hay and that these would be changed to positive if the alfalfa were fed fresh and green, but in the first trial positive balances were established on both dry alfalfa hay and fresh green alfalfa. There was, however, a more liberal storage of calcium on the fresh than on the dry alfalfa. Positive phosphorus balances were also obtained. The hay used in this experiment had been cured under caps and was of excellent quality. The authors concluded that "apparently the question whether positive or negative calcium balances will prevail in liberally milking cows through the use of such an efficient carrier of calcium as alfalfa hay is determined by the quality of the alfalfa hay used. By the term quality, used in this connection, we mean the relative degree of destruction in the curing processes of the unknown factors affecting calcium assimilation."

This conclusion was confirmed in other studies (*32*) in which negative calcium and phosphorus balances were obtained in milch cows receiving alfalfa hay which had been cured in the windrow, with exposure to air and light for four days. This difference was attributed to differences in the degree of destruction during the curing process of the vitamin which assists calcium assimilation. When timothy hay was used in place of alfalfa the negative balances were higher than in the alfalfa period. Supplementing the timothy hay with bone meal did not result in calcium equilibrium.

This line of investigation appears to open up a wide field of research and of practical application. Granting the importance in animal feeding of the antirachitic vitamin, or the vitamin assisting in calcium assimilation, advantage may be taken of the results already obtained in the study of experimental rickets to study the same problems in connection with the feeding of domestic animals; to determine, for instance, whether, as has been demonstrated in rats and children, light exerts the same effect as the antirachitic vitamin, to establish more completely the content of this vitamin in various green feeds, to develop better methods of drying and keeping such feeds as are

found to contain it, and to determine the most effective time to establish, by means of properly selected rations, the calcium and phosphorus reserves of farm animals, particularly dairy cattle.

GENERAL STATUS OF INVESTIGATION

The similarity in vitamin requirements of laboratory and larger animals has been sufficiently well established to make it safe in general to take advantage of the extensive and rapidly accumulating literature on vitamins in their relation to human nutrition and to apply the established principles to animal nutrition. The importance in normal nutrition of the fat-soluble vitamin has been definitely established, but is not yet fully appreciated. There is still considerable confusion concerning the identity, occurrence, and specific functions of the various factors included in the term, and the clearing up of this confusion by a more definite separation and examination of the fat-soluble vitamins will do much to simplify the problem of correct and efficient animal feeding.

REFERENCES

(1) The relation of growth to the chemical constituents of the diet. T. B. Osborne and L. B. Mendel. Jour. Biol. Chem., 15 (1913), p. 311.
(2) The necessity of certain lipins in the diet during growth. E. V. McCollum and N. Davis. Jour. Biol. Chem., 15 (1913), p. 167.
(3) The influence of butter fat on growth. T. B. Osborne and L. B. Mendel. Jour. Biol. Chem., 16 (1913), p. 423.
(4) The effect of vatamin deficiency on various species of animals.—I, The production of xerophthalmia in the rabbit. V. E. Nelson and A. R. Lamb. Amer. Jour. Physiol., 51 (1920), p. 530.
(5) Fat-soluble vitamin.—IX, The incidence of an ophthalmic reaction in dogs fed a fat-soluble vitamin deficient diet. H. Steenbock, E. M. Nelson, and E. B. Hart. Amer. Jour. Physiol., 58 (1921), p. 14.
(6) Fat-soluble vitamin.—VII, The fat-soluble vitamin and yellow pigmentation in animal fats, with some observations on its stability to saponification. H. Steenbock, M. T. Sell, and M. V. Buell. Jour. Biol. Chem., 47 (1921), p. 89.
(7) On an invariable and characteristic disturbance of reproductive function in animals reared on a diet poor in fat-soluble vitamin A. H. M. Evans and K. S. Bishop. Anat. Rec., 23 (1922), p. 17.
(8) On the existence of a hitherto unrecognized dietary factor essential for reproduction. H. M. Evans and K. S. Bishop. Science, 56 (1922), p. 650. Amer. Jour. Physiol., 63 (1922), p. 396.
(9) The influence of dry v. fresh green plant tissue on calcium assimilation. E. B. Hart, H. Steenbock, and C. A. Hoppert. Science, 52 (1920), p. 318.
(10) Dietary factors influencing calcium assimilation.—I, The comparative influence of green and dried plant tissue, cabbage, orange juice, and cod liver oil on calcium assimilation. E. B. Hart, H. Steenbock, and C. A. Hoppert. Jour. Biol. Chem., 48 (1921), p. 33.
(11) The effect of vitamin deficiency on various species of animals. V. E. Nelson, A. R. Lamb, and V. G. Heller. II, Observations on the comparative vitamin A requirement of rabbits, rats, swine, and chickens. Amer. Jour. Physiol. 59 (1922), p. 335. III, The production and cure of xerophthalmia in the suckling. Amer. Jour. Diseases Children, 23 (1922), p. 518.
(12) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 16. 1923.
(13) The nutritional requirements of baby chicks.—II, Further study of leg weakness in chickens. E. B. Hart, J. G. Halpin, and H. Steenbock. Jour. Biol. Chem., 52 (1922), p. 379.
(14) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 7. 1923.
(15) The therapeutic value of egg yolk in rickets. A. F. Hess. Jour. Amer. Med. Assoc., 81 (1923), p. 15.
(16) The antirachitic influence of egg yolk. H. Casparis, P. G. Shipley, and B. Kramer. Jour. Amer. Med. Assoc., 81 (1923), p. 818.

(17) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 9. 1923.
(18) Effect of confinement and green feed on number and hatchability of eggs. H. Atwood. West Virginia Sta. Bul. 178. 1922.
(19) Fat-soluble vitamin.—III, The comparative value of white and yellow maizes. H. Steenbock and P. W. Boutwell. Jour. Biol. Chem., 41 (1920), p. 81.
(20) Illinois Sta. Rpt. 1922, p. 16.
(21) Iowa Sta. Rpt. 1922, p. 37.
(22) Wisconsin Sta. Bul. 352 (Report of Director, 1922), p. 19. 1923.
(23) Ohio Sta. Bul. 362 (Rpt. 1922), p. XLVIII.
(24) Vitamin studies.—IX, The influence of the diet of the cow upon the quantity of vitamins A and B in the milk. C. Kennedy and R. A. Dutcher. Jour. Biol. Chem., 50 (1922), p. 339.
(25) Ohio Sta. Bul. 362 (Rpt. 1922), p. XLVI.
(26) The mineral metabolism of the milch cow. E. B. Forbes, J. A. Schulz, C. H. Hunt, A. R. Winter, and R. F. Remler. Jour. Biol. Chem., 52 (1922), p. 281.
(27) The mineral metabolism of the milch cow. First paper. E. B. Forbes, F. M. Beegle, et al. Ohio Sta. Bul. 295. 1916.
(28) The mineral metabolism of the milch cow. Second paper. E. B. Forbes, F. M. Beegle, et al. Ohio Sta. Bul. 308. 1917.
(29) The mineral metabolism of the milch cow. E. B. Forbes, C. H. Hunt, J. A. Schulz, A. R. Winter, and R. F. Remler. Ohio Sta. Bul. 363. 1922.
(30) Wisconsin Sta.Bul. 352 (Report of Director, 1922), p. 16.
(31) Dietary factors influencing calcium assimilation.—II, The comparative efficiency of dry and green alfalfa in maintaining calcium and phosphorus equilibrium in milking cows. E. B. Hart, H. Steenbock, and C. A. Hoppert. Jour. Biol. Chem., 53 (1922), p. 21.
(32) Dietary factors influencing calcium assimilation.—III, The comparative efficiency of timothy hay, alfalfa hay, and timothy hay plus calcium phosphate (steamed bone meal) in maintaining calcium and phosphorus equilibrium in milking cows. E. B. Hart, H. Steenbock, C. A. Hoppert, R. M. Bethke, G. C. Humphrey. Jour. Biol. Chem., 54 (1922), p. 75.

STATION INVESTIGATIONS ON FRUIT-BUD FORMATION

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The fact that profitable fruit production is primarily dependent upon the development of an adequate supply of flower buds renders the knowledge of the factors directly affecting such formation of immediate concern to the horticulturist. Nevertheless, the attainment of exact knowledge has been relatively slow, and only since investigators have begun to use the more exact methods of plant cytology, chemistry, and biometrics has real progress been evident. The early horticulturist knew from changes in the outward form that flower buds of certain fruits were differentiated in the season preceding blossoming; it remained for the investigator to determine the exact time the process occurs and the factors involved.

Fruit-bud differentiation.—The Wisconsin station (*40, 41, 43*)[2] was the first of the American stations to study the exact time of differentiation in fruits. This original work was remarkable, not only for the large number of species studied, but also for the accuracy of the deductions arrived at. It was concluded that the fruit bud is not essentially different from the leaf bud, but that differentiation is primarily dependent upon internal nutritional conditions at the time of cessation of vegetative growth. The recommendation made at this time, following the discovery that strawberry blossoms are differentiated in the fall, namely, that beds should receive better care in the autumn, accords with the conclusions reached many years later by the Missouri station (*14*).

Among other stations to contribute knowledge concerning the time of fruit-bud differentiation are Georgia (*3*), Virginia (*34*), Oregon (*26, 27, 28*), New Hampshire (*17*), and Iowa (*5*).

Effect of fertilizers.—The rôle that fertilizers play in stimulating fruit-bud formation has long been a subject of earnest inquiry, and many conflicting ideas have been advanced. The work of the New York State station (*23*), New Hampshire station (*15*), and Pennsylvania station (*32*) has shown that trees growing in naturally fertile soils under good cultural conditions do not respond in yield to fertilizers. On the other hand, the Oregon station (*31*) found that nitrate of soda not only stimulated the number of spurs to blossom, but also increased the percentage of fruit to set, and as a result increased the yield.

In short-lived and rapid-growing trees, such as the peach, it has been generally conceded that on relatively poor soils nitrogen fertilizers are highly essential; the West Virginia station (*37*), for example, noted that nitrate of soda greatly increased the number of fruit buds on peach trees. The Wisconsin station (*38*) found a definite correlation between the annual increase in length of Wealthy

[2] Italic numbers in parentheses refer to References, p. 92.

apple spurs and their blossom bud performance, the maximum production of buds being found to be correlated with spurs of moderate growth. This finding was later corroborated by the Iowa station (*6*), the Missouri station (*12*), and by the Illinois station (*4*). From these observations it is evident, therefore, that in orchards where nitrogen is a limiting factor in growth, fruit-bud formation being primarily dependent upon an adequate vegetative growth of the tree is in turn influenced by nitrogen applications.

The Missouri station (*13*) found that the time of application of nitrogen fertilizers is a very important consideration and recommended that fertilization should conform with the fruiting performance of the tree. On the other hand, potash and phosphoric acid have shown little value for orchard trees except as they stimulate the cover crop growth, which in turn affects the tree development. The significance of fertility practices in relation to fruit-bud formation was greatly clarified by the hypothesis advanced by the Oregon station (*29*); namely,, that fruitfulness in a plant depends primarily upon a satisfactory balance between nitrogen and carbohydrate contents. Much of the intense interest recently manifested by the station workers in fruit-bud performance may be directly traced to this fundamental contribution.

Effect of soil treatment.—That soil management has a material effect on fruit-bud formation was noted by the New York State station (*22*) which reports that trees in tillage were much more productive than those in sod. The New Hampshire station (*16*) found that Baldwin trees in tillage and those in tillage plus cover crops were more productive of fruit buds in the off season than were trees in sod. This fact was also noted by the Iowa station (*7*) and the Virginia station (*35*). The Oklahoma station (*25*) found that mulching with straw tended to increase fruit-bud formation in the peach and in the cherry. The Wisconsin station (*44*) found in supplying water during a drought to one of a pair of Gideon apple trees that an abundant water supply had no stimulating effect upon fruit-bud development, either in respect to time of differentiation or in percentage of fruit buds formed.

Effect of pruning, defoliation, and girdling.—The effect of pruning upon fruit-bud formation has been studied by many of the stations. At the Virginia station (*33*) it was found that spring pruning of dwarf apple trees tended to discourage, summer pruning to encourage, and fall pruning to have little effect upon fruit-bud formation. The California station (*1*) noted that lightly pruned fruit and nut trees came into bearing from one to three years earlier than did similar severely pruned trees. The deleterious effect of severe pruning upon immature trees has also been studied by the New York Cornell station (*21*), the New York State station (*24*), the New Jersey stations (*20*), the Massachusetts station (*8*), and the California station (*2*).

At the Wisconsin station (*38*) it was found that the biennial bearing tendency in the Wealthy apple could be partly overcome by moderate pruning in the off-bearing year. At the same station (*42*) it was observed that partial defoliation of pear spurs hastened fruit-bud formation. The Oregon station (*30*) reported that defoliation of spurs early in the season strongly hindered fruit-bud formation in 7-year-old apple trees, and concluded that the apple spur possesses individuality in a high degree. The Missouri station (*12*), completing a biometrical study of the bearing habit in annual and

biennial fruiting apple trees, concludes that the factors influencing spur performance are localized narrowly at times, widely at others, and that in all cases studies of the factors determining fruit-bud differentiation should not be confined to the spur alone.

Studies with American plums at the Wisconsin station (*39*) indicated that early defoliation may cause an entire absence of fruit-bud formation, but that later defoliation may have little or no inhibitory effect. The Massachussetts station (*9*) found that girdling stimulated fruit-bud formation in 7-year-old apple trees carrying little or no fruit, whereas the same treatment had no effect on more productive trees.

Effect of light.—Studies upon the effect of light on fruit-bud formation have been reported from the New Hampshire station (*18*) and the Wisconsin station (*46*) and in general have shown that the reduction of light during the growing season results in the practical elimination of fruit-bud development. The New Hampshire station (*19*) asserts that the cessation of fruit-bud formation beneath shade is due either to a reduction in carbon assimilation or an increase in nitrogen intake, or perhaps to a combination of both of these causes.

Chemical studies.—As has been previously indicated, chemical studies of various kinds have materially contributed to the advance in knowledge of fruit buds and their development. The work of the Oregon station (*29*), already mentioned, has been followed by contributions from other stations upon the same general subject. The Missouri station (*10*), studying factors promoting fruitfulness and nonfruitfulness in apple spurs, reported sugar and starches to be slightly more abundant in productive than in nonproductive spurs, and at the same time noted that apple spurs are most productive between the ages of 3 and 7 years. The Oregon station (*30*) found that defoliation of apple spurs modified their chemical composition, resulting in a sharp increase in nitrogen constituents and a decrease in carbohydrates. The Wisconsin station (*45*) reports that blossom-bud formation occurred most abundantly in apple trees which contained an intermediate percentage of nitrogen and the reciprocal condition of an intermediate percentage of carbohydrates.

Analyses reported by the New Hampshire station (*19*) of the last two years' growth of two alternate bearing apple trees fruiting in different years showed fruiting trees to be slightly higher in moisture and in total nitrogen. Investigations at the Virginia station (*36*) indicated that early spring applications of nitrate of soda were more effective in promoting growth and yield than were later applications. Determinations by the Missouri station (*11*) upon the chemical contents of apple spurs collected at intervals during the year showed seasonal changes in composition distinct and characteristic of the condition of the spur in relation to productivity. Conditions leading to high starch and low nitrogen conditions at the time of fruit-bud differentiation were found essential to productivity.

Summary.—Experimental activities relating to the underlying causes of fruit-bud formation date back to only about the beginning of the present century; and although much knowledge has been acquired in this brief period concerning the time of differentiation of flower buds in various fruits, only an inkling has been obtained concerning the nutritive conditions associated with such formation. Progress in the latter subject is largely due to the lucid theory elab-

orated by Kraus and Kraybill; namely, that fruitfulness is dependent upon a satisfactory balance between the nitrogen and carbohydrate contents of the plant itself. Formation of flower buds is dependent upon an accumulation of carbohydrates above that required for purely vegetative development. On the other hand, an excess of nitrogen leads to a rapid utilization of carbohydrates, thus preventing their accumulation. Present knowledge, though meager, is sufficient for the formulation of rational plans for pruning, fertilization, and cultivation based on the actual needs of the tree rather than on empirical results of practice. Maximum production of fruit buds is apparently correlated with vigorous but not excessive vegetative growth.

In the light of present knowledge, it is highly possible that one of the serious problems besetting fruit growers, namely, that of overcoming the tendency of many important apple and pear varieties to fruit biennially, may be solved. Again, the tendency for fruit trees to overbear, with the consequent necessity of thinning the fruits or supporting the limbs, may be partially overcome by more enlightened practices of fertilization and pruning. In view of the active interest that many of the stations are now taking in fruit-bud studies, there is every reason to look forward to valuable progress in the near future.

REFERENCES

(1) Pruning young deciduous fruit trees. W. P. Tufts. California Sta. Bul. 313. 1919.
(2) Pruning young olive trees. F. T. Bioletti. California Sta. Bul. 348. 1922.
(3) Georgia Sta. Rpt. 1900, p. 350.
(4) The effect of certain potassium and nitrogen fertilizers on the shoot growth and flower formation of the peach. W. A. Ruth. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 152–160.
(5) A study of the formation and development of the flower buds of Jonathan and Grimes Golden in relation to different types (clover sod, blue-grass sod, cover crop, and clean tillage) of soil management. R. S. Kirby. Iowa Acad. Sci. Proc., 25 (1918), pp. 265–287.
(6) Factors which influence the production and growth of fruit buds on the apple. T. J. Maney and H. H. Plagge. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 100–103.
(7) Fruit bud production in the apple. T. J. Maney and H. H. Plagge. Amer. Soc. Hort. Sci. Proc., 17 (1920), pp. 250–256.
(8) Recent developments in the practice and principles of pruning. J. K. Shaw. Vt. State Hort. Soc. Ann. Rpt., 18 (1920), pp. 24–31.
(9) An experiment in ringing apple trees. J. K. Shaw. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 216–220.
(10) Some factors favoring or opposing fruitfulness in apples.—The effect of certain conditions and practices on the development and performance of the individual fruit spur. C. C. Wiggans. Missouri Sta. Research Bul. 32. 1918.
(11) Seasonal changes in the chemical composition of apple spurs. H. D. Hooker, jr. Missouri Sta. Research Bul. 40. 1920.
(12) Localization of the factors determining fruit bud formation. H. D. Hooker, jr., and F. C. Bradford. Missouri Sta. Research Bul. 47. 1921.
(13) Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. H. D. Hooker, jr. Missouri Sta. Research Bul. 50. 1922.
(14) Studies in the nutrition of the strawberry. V. R. Gardner. Missouri Sta. Research Bul. 57. 1923.
(15) The effects of fertilizers in a cultivated orchard. J. H. Gourley. New Hampshire Sta. Bul. 168. 1914.
(16) Studies in fruit-bud formation. J. H. Gourley. New Hampshire Sta. Tech. Bul. 9. 1915.
(17) The nature of the inflorescence and fruit of *Pyrus malus*. C. A. Black. New Hampshire Sta. Tech. Bul. 10. 1916.

(18) The effects of shading some horticultural plants. J. H. Gourley and G. T. Nightingale. New Hampshire Sta. Tech. Bul. 18. 1921.
(19) Effect of shading and ringing upon the chemical composition of apple and peach trees. H. R. Kraybill. New Hampshire Sta. Tech. Bul. 23. 1923.
(20) Some results of pruning investigations with peaches. M. A. Blake. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 213–222.
(21) Results of some experiments in pruning fruit trees. W. H. Chandler. New York Cornell Sta. Bul. 415. 1923.
(22) Is it necessary to fertilize an apple orchard? U. P. Hedrick. New York State Sta. Bul. 339. 1911.
(23) Twenty years of fertilizers in an apple orchard. U. P. Hedrick and R. D. Anthony. New York State Sta. Bul. 460. 1919.
(24) Growth and yield of apple trees pruned in various ways. G. H. Howe. New York State Sta. Bul. 500. 1923.
(25) Oklahoma Sta. Rpt. 1919, p. 47.
(26) The pollination of the pomaceous fruits.—I, Gross morphology of the apple. E. J. Kraus. Oregon Sta. Research Bul. 1, pt. 1. 1913.
(27) The pollination of the pomaceous fruits.—II, Fruit-bud development of the apple. F. C. Bradford. Oregon Sta. Bul. 129. 1915.
(28) The influence of summer pruning on bud development in the apple. J. R. Magness. Oregon Sta. Bul. 139, pp. 46–67. 1916.
(29) Vegetation and reproduction with special reference to the tomato. E. J. Kraus and H. R. Kraybill. Oregon Sta. Bul. 149. 1918.
(30) The relation of carbohydrates and nitrogen to the behavior of apple spurs. E. M. Harvey and A. E. Murneek. Oregon Sta. Bul. 176. 1921.
(31) The influence of nitrogen upon the vigor and production of devitalized apple trees. C. I. Lewis and R. W. Allen. Oregon Sta. Rpt. Hood River Branch Sta. 1915, pp. 5–19.
(32) Methods of interpreting yield records in apple fertilization experiments. R. D. Anthony and J. H. Waring. Pennsylvania Sta. Bul. 173. 1922.
(33) Some effects of pruning, root pruning, ringing and stripping on the formation of fruit buds on dwarf apple trees. A. W. Drinkard, jr. Virginia Sta. Tech. Bul. 5. 1915.
(34) Fruit-bud formation and development. A. W. Drinkard, jr. Virginia Sta. Rpts. 1909–10, pp. 159–205.
(35) Virginia Sta. Rpt. 1919, p. 8.
(36) Effect of time of application of nitrogenous fertilizers on tree growth, bloom and fruit production. G. S. Ralston. Amer. Soc. Hort. Sci. Proc, 18 (1921), pp. 118–123.
(37) The fertilization of peach orchards. W. H. Alderman. West Virginia Sta. Bul. 150. 1915.
(38) Off-year apple bearing and apple spur growth. R. H. Roberts. Wisconsin Sta. Bul. 317. 1920.
(39) Effect of defoliation upon blossom bud formation. R. H. Roberts. Wisconsin Sta. Research Bul. 56. 1923.
(40) The origin and early development of the flowers in the cherry, plum, apple and pear. E. S. Goff. Wisconsin Sta. Rpt. 1899, pp. 289–303.
(41) Investigation of flower buds. E. S. Goff. Wisconsin Sta. Rpt. 1900, pp. 266–285.
(42) Wisconsin Sta. Rpt. 1900, p. 280.
(43) Investigation of flower buds. E. S. Goff. Wisconsin Sta. Rpt. 1901, pp. 304–316.
(44) Wisconsin Sta. Rpt. 1901, p. 312.
(45) Nitrogen reserve in apple trees. R. H. Roberts. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 143–145.
(46) Light in relation to the growth and chemical composition of some horticultural plants. G. T. Nightingale. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 18–29.

PROGRESS IN AGRICULTURAL ENGINEERING AT THE STATIONS

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INTRODUCTION

Agricultural engineering has steadily progressed in recent years, first as a teaching subject, then as a service branch, and is now gradually taking its place in the field of investigation at the experiment stations. Although considerable progress has been made in providing a broad, general background, and to a certain limited extent in formulating purely agricultural engineering principles, the development of inquiry along advanced lines has been slow.

The project lists of the experiment stations show a relatively small but gradually increasing number of projects in the field of agricultural engineering. The latest of such lists includes 162 projects, distributed as follows: Land clearing 12, drainage 19, farm buildings 19, farm machinery 31, farm power 11, farm water supply and sewage disposal 9, irrigation 36, materials of construction 21, and miscellaneous 4. Twenty-eight experiment stations are represented in this work in the following States: Idaho, Wyoming, Minnesota, Oregon, Wisconsin, Alabama, Illinois, Michigan, California, Mississippi, Montana, North Carolina, Iowa, Kentucky, Indiana, Arkansas, Nebraska, New York, West Virginia, Missouri, New Jersey, Colorado, Utah, Arizona, New Mexico, Nevada, Pennsylvania, and Ohio. The experiment station on the island of Guam is also represented.

The majority of the agricultural engineering projects have until recently been rather elementary, relating to the design of structures, comparisons of farm equipment or methods, and similar subjects; but such elementary projects have proved to be very necessary in some cases in the evolution of projects of research grade. They have not only served to point out numerous lines of inquiry in which it is desirable that the underlying facts and principles be determined but have brought out the importance of planning and executing investigational work with a logical starting point and a definite aim in each instance.

FARM MACHINERY

Some of the most striking examples of investigation of a rather elementary character have occurred in the field of farm machinery.

Tractors.—Tractors of different types, sizes, shapes, and general characteristics were thrown on the market several years ago. These gradually increased in number and the State colleges and experiment stations were besieged with inquiries. This naturally led to comparative tests of one kind or another to meet immediate demands for information, and at one time national and even international tests and demonstrations of a comparative nature were held.

From these tests the necessity for more specific studies of tractor characteristics in relation to farming requirements became evident. Accepting engine and transmission characteristics and functions as purely mechanical engineering matters, several of the experiment stations began to look into operating characteristics in actual farm work. Considerable general work had, of course, been done previously by commercial concerns in the development of specific tractor types, but nothing of a very fundamental nature had been brought out.

It developed that the relation of lug equipment of drive wheels to traction is one of the most important factors in the farm-tractor problem. Numerous comparative tests of different sizes and shapes of drive-wheel equipment were conducted by both public and private institutions at considerable expense, to determine which would give the best results over a wide range of soil types. Among these, the tests at the Indiana station (*1*)[3] may be particularly mentioned. These and several other similar tests from different sources were described in some detail by R. U. Blasingame in a contribution from the Pennsylvania station (*2*). These tests indicated the complexity of the problem of traction under farming conditions, and led M. L. Nichols and J. W. Randolph, of the Alabama station, to undertake a study of the fundamental factors influencing the traction of wheel tractors, with particular reference to Alabama soils. This work resulted in the first Adams fund project ever established in this branch of agricultural engineering at a State agricultural experiment station. The first annual report of this project is in course of preparation.

It is significant to note that the main premise adopted in this project was that traction is primarily a function of soil conditions and secondarily of the design of the tractor wheel, evidently a fundamental conception. It was therefore planned to determine first what soil factors affect traction, the relation and valuation of these factors, and more specifically the lines of maximum, minimum, and intermediate resistance to traction in the soil. The next step was to determine the factors of tractor-wheel design, including materials, shape, size, location, and inclination of lugs necessary to meet the soil conditions imposed. Thus the ultimate object was to devise tractor-wheel equipment which would deliver the maximum components of impulsive force along the lines of maximum resistance in the soil.

The results to date, although far from complete, have led to the tentative conclusions that the distribution of impulsive forces in the soil can be accurately determined. The amount and efficiency of traction are increased in sand up to 8 per cent moisture content and are decreased at 16 per cent moisture content. Clay permits better traction than sand except under extreme moisture conditions. The point of greatest efficiency or permissible slip is not constant, occurring later in dry loose soils than in moist compressed soils. A close relation was established between the traction developed by a slowly rotating wheel when advancing and the force exerted by a stationary rotating wheel. A relationship was also established between traction and bearing value, resistance to penetration, and shearing strength of soils. Hardness, cohesive, adhesive, fractional, and puddling properties, tenacity, and plasticity are other soil factors which have assumed considerable importance in this work.

[3] Italic numbers in parentheses refer to references, p. 109.

The problem under such analysis has thus resolved itself primarily into one of soil dynamics and the influence thereof on traction. The failure of previous work to yield fundamental information regarding traction obviously has impressed the investigators with the importance of beginning the work with a consideration of the requirements of the thing most vitally concerned, the soil.

Tillage machinery.—Everything indicates that the more or less neglected soil factor really constitutes the logical starting point for many studies of tillage machinery and should profoundly influence their ultimate trend. For example, E. V. Collins at the Iowa station, in studies on factors influencing the draft of plows (*3, 4, 5*), showed that the type of plow bottom does not materially influence the draft, and that an increase in speed will produce about the same increase in draft with any type of bottom. The increase in draft due to speed was found to be confined to that part of the total which is required for turning and pulverizing, and varied with the speed from less than one-third to about one-half the total draft of the plow within a speed range of from 2 to 4 miles per hour. Under some plowing conditions a sharp cutting edge was of little importance, and under certain conditions high speeds caused failure to scour. These results indicate the primary importance of soil mechanics as the controlling factor.

Other plowing tests by J. B. Davidson and Collins at the Iowa station (*6*) and of a large number of plowing tests by O. W. Sjogren at the Nebraska station (*7*), by M. M. Jones at the Missouri station (*8, 9*), and by A. H. Hoffman at the California station (*10*) indicated the importance of the soil as a factor for primary consideration in studies of tillage machinery. This was also brought out in a large number of disk harrow tests by Hoffman and E. J. Stirniman at the California Station (*11*), by Sjogren at the Nebraska station (*7*), by Jones at the Missouri station (*9*), and by Collins at the Iowa station (*12, 13, 14*).

In a more fundamental study of the plow bottom and its action on the furrow slice, at the New York Cornell station (*15*), E. A. White attempted to develop a theory for the design of plow bottoms. The results, while inconclusive, gave reason to believe that there is a mathematical form to which the surface of the plow bottom should conform, in view of the fact that the soil particles follow very definite paths when passing over the surface of the moldboard. This work also pointed to the soil as the logical starting point of such investigations.

With this same thought in mind, Hoffman at the California station planned a study which was originally intended to devise a method of measuring the coefficient of static and kinetic friction between any given soil and polished metal surfaces, but which was finally reduced to a study of the factors governing static friction between the metal surfaces of farm machines moving through or over soil and different soil types.

Nichols at the Alabama station undertook to develop an even more fundamental conception of the influence of the soil factor on the operation of traction and tillage machines (*16*). He has pointed out the needs of research along the lines of soil dynamics which will be peculiarly applicable to agricultural engineering requirements. He

has also shown that seed-bed preparation and cultivation, as well as traction, are processes, the efficiency of which depends upon adapting the implement to the mechanical properties of the soil.

A survey of work on tillage and tillage machinery at a number of the experiment stations and by several private commercial concerns has shown the necessity for an entirely new classification of soils and their properties with reference to the engineering aspects of tillage. With this in view, Hoffman at the California station has devised a method for measuring and standardizing the state of tilth of soil (*17*). This method involves the use of six screens of different mesh sizes, placed one above the other, the top screen having an 8-inch mesh, the next a 4-inch mesh, and so on down to the bottom screen, with a 0.25-inch mesh. The soil sample, taken to the depth of tilth in an undisturbed condition, is gently deposited upon the top screen, and the percentage by weight retained by each screen is recorded. Only the 0.5 and 0.25 inch screens are shaken. Curves platted from such data show the states of tilth in different soils and the tendencies of tillage operations in influencing tilth conditions. This method has been recommended as a standard for indicating state of tilth by the Research Committee of the American Society of Agricultural Engineers.

Air cleaning of tractor motors.—The work on air cleaning for tractor motors is another interesting instance of the evolution of research in agricultural engineering. The need for work of this character was reflected in a number of the so-called tractor surveys, which have been conducted from time to time by the experiment stations in nearly every State where tractors are used to any extent. This need seems to be especially important in some of the far Western and Southern States where extremely dusty conditions prevail during parts of the year. A large amount of work of an empirical nature has been done on this subject at great expense by manufacturers of tractor accessories and equipment, but has been limited to the development of mechanical devices.

In preliminary work at the California station (*18*), Hoffman tested 26 air cleaners for tractor motors representing all the more prominent makes and types, the purpose being to compare the dust-separating efficiency, vacuum effect, and effect on maximum possible power of the motor of the different cleaner types. These cleaners included 8 of the dry type, 9 of the water type, and 9 of the oil type. The results showed that the oil types gave the most uniformly efficient results, followed in order by the water and dry types. The effect on power of the engine was found to be negligibly small for the average of each group, but the results were not final.

In further work (*19*) Hoffman developed methods of testing dust-separating efficiency (*20*). In order that all air cleaners might have to meet the same conditions, a standard dust was made up from ten 50-pound samples of field soils taken from 10 regions in California where tractor motor wear due to dust conditions is very rapid. By a pulverizing and air floating process, the dustier portions were separated from the rest. This air-floated portion constituted 99 per cent of the standard dust used, and the other 1 per cent was a very fine sand. A small circular brush revolved by a motor swept the dust into the stream of air entering the cleaner under test, and the rate of feed was varied by use of screws of different pitches and by

varying the period of a contact pendulum which operated the screws. Although the testing methods constituted a valuable contribution, the results of the cleaner tests were apparently only of comparative value; but the experience gained indicated the importance of giving more consideration to the thing most vitally concerned, the dust itself.

Nichols at the Alabama station undertook to learn more about the fundamental scientific principles governing the dust and its movement in an air cleaner, and its consequent maximum removal from the tractor air intake within a given range of partial vacua caused by intake suction and within a given range of amount and of physical, mechanical, and chemical composition of dust. He finally arrived at the tentative conclusion that the solution of the problem rests upon the determination of the factors governing the so-called decolloidization of the dust floating or suspended in the air. His theory is that once the air-floated dust is flocculated it can be controlled and removed by known mechanical principles. Further investigations on the subject are in progress to indicate the principles which, when embodied in any air cleaner, will cause the maximum practicable dust removal under the conditions imposed.

Side draft.—Hoffman at the California station (*21*) has shown that side draft, the stumbling block in many mechanical tillage devices, is governed by the laws of mechanics that apply to forces in general, and is always in evidence if the resisting force of the implement pulls to one side instead of parallel to the direction of motion. He found that no hitch, patented or otherwise, can prevent side draft when the center lines of pull of a tractor and of resistance of an implement are offset and the hitch is to the center of a symmetrically placed drawbar, but that it can be removed by making these lines coincident.

E. A. White, in a study of equalizers and hitches at the Illinois station (*22*), evolved a mathematical method by which equalizers and hitches may be analyzed, thereby affording a means of making fundamental comparisons and when desired of predicting the results as regards side draft, especially what may be expected in a given case.

Miscellaneous machinery.—Davidson and Collins, of the Iowa station, working in cooperation with the soils department of the station, recently completed a study of limestone and fertilizer spreaders (*12*, *23*). Tests of commercial limestone spreaders and a study of the various methods of handling limestone indicated requirements and desirable features of a limestone spreader which eliminated all the commercially available types. The results pointed the way to the development of an effective machine which took the form of a trailer behind a loaded wagon, using a revolving finger type of distributor. This case illustrates an effective way to proceed in such matters, in that it began with a study of what a limestone spreader should do, with special consideration of the properties of the limestone itself, passed through the stages of testing available machines and establishing the engineering principles on which an efficient machine should be constructed, and ended with the actual construction of a satisfactory machine.

F. W. Duffee, of the Wisconsin station, in elaborate tests of the relative efficiencies of 20 different silage cutters and fillers (*24*), revealed a broad variation in the power requirements of different

machines performing the same function, thus indicating that light-draft machines are more the result of perfection of design than of type. The necessity for fundamental studies of the requirements of the processes which must be met by these machines to serve as a basis for their development was thus made evident.

G. R. B. Elliott and J. L. Larson, of the Minnesota station, in their experiments on the first breaking of peat lands (*25*), found it necessary to develop special types of marsh plows. Here was a case in which studies along one line brought out the necessity of conducting studies along another line before the first studies could be completed—a not unusual occurrence in a relatively new subject such as agricultural engineering.

FARM STRUCTURES

There is a long record of work on farm buildings at the experiment stations, most of which, however, has been merely an application of well-known engineering knowledge and skill in the design of farm structures, frequently as a purely service function. Previous to the year 1922 almost every State agricultural college and experiment station engaged in some such work, but instances of serious research in this field have been rare.

Elevators.—The Iowa station was one of the first to recognize the importance of putting the studies of farm buildings on a fundamental basis. W. G. Kaiser and W. A. Foster, of that station, conducted studies of farm elevators (*26*) which brought out clearly the importance of logical starting and finishing points in farm-building studies, and also illustrated the application of engineering and purely scientific principles to such work. The studies began with a consideration of the requirements of the thing most vitally affected, the grain, and ended with the development of elevators designed to handle the grain with a maximum of efficiency.

Roofs.—Another instance worthy of mention is the work at the Iowa station by F. C. Fenton and A. W. Clyde (*27*), which was developed by Clyde into a specific study of self-supporting barn roofs (*28*). These studies dealt primarily with roofs for different types of barn. Significant conclusions from the first studies were that practically nothing definite is known of the strength of ordinary barn roofs, and that none of the common types will withstand a wind of 90 miles per hour. The results were taken to indicate the need for studies of the stength of the various types of roof with a view to evolving rational methods of design to meet the requirements of self-supporting roofs.

Tests by Clyde and H. Geise (*29*) of a masonry-arch barn roof, consisting of three reinforced concrete arch ribs filled in between with reinforced clay block, showed that the breaking load was approximately four times that produced by a 90-mile wind and that the design was much heavier than is required in practice. This would point to the necessity for a more thorough study of strength requirements of barn roofs, as a basis for design.

Silos.—A considerable amount of work on silos has been done at a number of the stations, much of which has consisted largely of comparative tests of different types of structure to suit the requirements of different materials. However, the work at the Iowa station began

with a consideration of the requirements of silage making and preservation. The early work of Davidson and M. L. King (*30*) indicated that the essentials of good silo construction require air-tight walls and doors, walls smooth inside and rigid enough to withstand the pressure of the silage, and an air space between the walls to prevent freezing. Further work by Davidson and King (*31*) resulted in the development of the silo constructed of reinforced hollow clay building blocks, which embodied nearly all the essential requirements for proper silage making and preservation. Subsequent work by Davidson (*32*) and by C. K. Shedd and W. A. Foster at the Iowa station (*33*) resulted in the further fundamental development of types adapted to special conditions, such as the wooden hoop, pit, and monolithic concrete silos.

Further studies at the Iowa station on the influence of silo wall construction on the freezing of silage (*34*) showed that during cold weather the temperature at the inside of the north wall is only a little warmer than the outside temperature for wood-stave, hollow-tile, or monolithic-concrete silos. This resulted in the conclusion that there is no practical difference between the insulating properties of the three types of construction.

In accordance with a similarly fundamental conception of the silo problem, S. I. Bechdel conducted studies at the Pennsylvania station on the preservation of corn silage (*35*) in wood-stave, concrete-block, hollow-clay-block, and monolithic-concrete silos. These indicated that maximum temperatures higher than 80° F. are not necessary, that the total acidity of silage near the center is greater than that near the walls, and that near the walls there is proportionately more acetic and less lactic acid due to less firm packing. The proportion of lactic acid developed in stave silos was higher than in the concrete types, but otherwise there were no characteristic differences in the chemical composition of the silages made in the different silos.

With these results apparently in mind, studies conducted at the Iowa station (*36*) on means of making impervious silo walls constructed of porous materials showed that the application of bituminous material to the surface, by first sizing with a solution of the bitumen and later with a hot application, most satisfactorily resisted the action of the silage and had little tendency to peel or scale off.

Studies were also conducted at the Nebraska station by L. W. Chase (*37*) on the weight and capacity requirements of silage as a basis for the design of silos for structual strength. This work was elaborated at the Kansas and Missouri stations by C. H. Eckles, O. E. Reed, and J. B. Fitch (*38, 39*) and established the fact that the weight of silage is subject to so much variation that no table of silage weights and silo capacities can be more than approximately correct. Thus the importance of further fundamental development of silos to meet economically and effectively the requirements for the proper curing and preservation of silage is plainly evident.

Ventilation.—Considerable interest has been awakened recently in the ventilation of farm buildings not only for animal shelter but for crop storage as well, and the United States Department of Agriculture and several of the stations have entered into investigations of various phases of the subject.

In a study of some of the fundamentals of stable ventilation, H. P. Armsby and M. Kriss, of the Institute of Animal Nutrition of the Pennsylvannia State College, in cooperation with the United States

Department of Agriculture (*40*), attempted to show how the results of direct determinations of the heat production of cattle and other stock may be applied to the problems of stable ventilation, and how the heat production in any specific case may be computed with a fair approximation to accuracy. The results showed that the best thermal surroundings for animals should be between a temperature somewhat above the critical point, and one not so high as to affect the appetite and thrift of the animal. The conclusion was drawn that furthur fundamental investigation is needed to determine more clearly the requirements of the animals as a basis for the intelligent provision of properly ventilated stables.

Using the results of the above study as a basis, M. A. R. Kelley, of the United States Department of Agriculture, studied the factors influencing the operation of dairy barn ventilation systems, with particular reference to the forced-draft system (*41*). On the basis of the Armsby data for dairy cows, the results showed that as the total heat lost by ventilation and radiation decreased, the temperature inside increased. Estimating the heat production from the individual weight of each cow, the results showed that with the fan system of ventilation 43.7 per cent of the heat generated by the animals was lost by ventilation and 23.5 was lost by radiation.

In considering the design of outtake flues for dairy barn ventilation with a natural draft system on the basis of the heat and carbon-dioxid production of dairy cows, J. L. Strahan, of the Massachusetts station, showed that different breeds of dairy cows present different requirements (*42*). It was found that with a natural draft system it will be reasonable to expect Holsteins to maintain in zero weather a temperature above freezing in a stable 36 by 80 feet inside and housing 40 cows, and at the same time possible to maintain adequate ventilation conditions. On the other hand, it was shown that if Jerseys in low production are housed the stable temperature will drop below 32° F. as soon as the outside temperature goes below 6° if the same rate of air flow through the stable is maintained. Under these conditions the air flow would have to be reduced over 1,200 cubic feet per cow in order to keep the inside temperature up, which would tend to lower the ventilation standard considerably. It is further shown that small Jersey cows on maintenance alone can maintain a temperature difference of from 15° to 17° in well-constructed stables, and it is considered correct to assume that outtake flues may be designed to pass the required amount of air through a stable at a minimum temperature difference of 20° F.

Kelley undertook a further study of the factors influencing the design and operation of animal-barn ventilation systems, in cooperation with several of the State experiment stations, special attention being paid to horse, hog, and dairy barns (*43*). This study showed definitely that the factors influencing the maintenance of the desired temperatures in animal shelters are (1) insulation, (2) tightness of construction, (3) amount of air space each animal is expected to heat, and (4) the desired amount of ventilation in accordance with the type of animal housed and methods used in securing it. One significant conclusion drawn was that further research is needed on the requirements of horses in particular, upon which to base horse-barn design and ventilation.

In further studies of hog-house ventilation conducted at several of the experiment stations (*44*), Kelley showed the possibility of maintaining a reasonably uniform temperature in a barn housing a total weight of 26,775 pounds of hogs by regulating the amount of intake openings. This work also indicated the need for further study of the requirements of hogs and of the factors influencing and producing uniform temperature conditions.

Further studies by Kelley (*45*), in cooperation with the Maine, New York Cornell, and Nebraska stations, on the ventilation of animal shelters and poultry houses, indicated the necessity for more fundamental studies of the ventilation requirements of animals and poultry under exactly controlled conditions. This would suggest the utility in such studies of experimental processes and apparatus similar to those used in respiration calorimetric studies.

Crop storage.—The development of buildings and structures for the storage of crops is a problem of considerable importance in some localities. The importance in such work of careful consideration of the requirements of the crop and its behavior under storage conditions before undertaking to develop storage buildings can not be too strongly emphasized.

Thus studies on the development of potato warehouses by F. E. Fogle at the Michigan station (*46*) began with a consideration of the ventilation, temperature, and moisture requirements of the potato itself and of its rotting tendencies in storage, and proceeded ultimately to the development of the warehouse equipped with a suitable ventilation system for Michigan conditions.

Studies at the Delaware station by T. F. Manns on sweet potato storage in Delaware (*47*) dealt first with diseases of the sweet potato and the influence of moisture, ventilation, and temperature upon storage rots of sweet potatoes, as basic considerations in the development of storage houses and ventilation systems.

These and many other studies at the stations on crop storage show how consideration of the requirements of the crop and its behavior under storage furnishes a basis for the intelligent development of storage structures, and that cooperation between the agricultural engineer and other specialists is of great importance in such work.

DRAINAGE AND IRRIGATION

Other branches of agricultural engineering which merit the same consideration are drainage and irrigation. Numerous unsolved and very pressing problems are offered by each of these branches, and many of them appear to be susceptible of treatment and solution by the same general methods of attack applicable to problems in farm machinery and structures.

Drainage.—Drainage, for instance, is a subject upon which a large amount of work, mostly of a service nature, has been done. With the exception of the studies at the Missouri station on water absorption, run-off, percolation, evaporation, capillary water movement, and erosion under field conditions (*48*), there is practically no record of fundamental studies on this subject by the experiment stations. A consideration of the soil, beyond rather vague empirical treatment, has seldom been undertaken in this country as a basic consideration and logical starting point in drainage studies. Certain foreign agri-

cultural experiment stations, however, have taken the view that the soil and the crop to be grown are the things most vitally concerned in drainage, and have based their investigations on this conception.

A step in this direction was taken recently in studies of underdrainage at the North Carolina station, in cooperation with the United States Department of Agriculture, by H. M. Lynde (*49*). The results indicated that the texture of the soil is the controlling factor in the efficiency of underdrainage, and that in nonhomogeneous soils the spacing and depth of drains should be such as to suit average soil conditions as nearly as possible, and emphasized the importance of studying the influence of the physical and chemical properties of the soil and of different soil treatments and crops on underground run-off.

Investigation on the drainage of irrigated lands has recently been given considerable impetus by several of the experiment stations in the arid and semiarid States. W. W. Weir, in discussing the work by the California station (*50*), has summarized the situation, bringing out particularly the importance of the soil itself as the thing most vitally affected and the factor of primary importance from the standpoint of investigations.

Irrigation.—Irrigation is an agricultural engineering subject which has received much attention at the experiment stations. Practically every experiment station in the irrigated States has had projects in irrigation at one time or another, and there is a record of at least 40 active projects in 12 States. Some of these are obviously too indefinite or general to lay claim to a research status. Many, however, are planned along research lines. The studies have covered almost all phases of irrigation; but it seems that the fundamental factor, the soil, has received relatively little study in its relation to irrigation.

With this factor in view, O. W. Israelsen and F. L. West have conducted studies at the Utah station on the capacity of soils in the natural field condition to absorb and retain irrigation water (*51*). The significant conclusion was drawn that, as a general rule, soils have the capacity to absorb from 0.5 to 1.5 inches of water to each foot of depth of soil that needs moistening, and that the actual capacity of a given soil depends upon its texture and structure. Sandy or gravelly soils naturally retain the smaller amounts and clay loam soils the larger amounts.

Moisture studies of 670 soil samples at the Washington station by R. P. Bean (*52*), conducted principally in connection with border irrigation experiments, showed that, generally speaking, most of the moisture was held in the first 4 feet. Only under exceptionally heavy irrigation did the samples show any pronounced increase of moisture in the fifth and sixth foot. Lateral distribution of the moisture was very uniform, and under experimental conditions 24 hours was sufficient for the irrigation moisture to reach the soil moisture vertically and the soil moisture 36 inches away horizontally.

Studies by Israelsen and L. M. Winsor at the Utah station (*53*), on the net duty of water for staple crops on gravelly sandy loam and fine sandy loam soils, were begun by a consideration of the average permeability of the soils and their maximum capacities for absorbing and retaining water. On this basis the experiments were extended to show the proper use of water on such crops as beets, potatoes, and alfalfa.

The extensive work at the California station on different phases of soil moisture and its movement in relation to irrigation furnishes perhaps the most comprehensive view of the significance of the soil and its hydraulic characteristics as a prime factor in irrigation studies (*54*, *55*). These have brought out especially the significance of such factors as capillarity, evaporation tendencies, organic matter content, and cultivation.

These and numerous other studies indicate that not enough is yet known regarding the hydraulic properties of soil to furnish a sufficiently substantial basis for drainage and irrigation studies. A review of the soils projects at the different experiment stations indicates that there are in operation at least 19 projects at as many stations on the relation of soil moisture and soil moisture movement to the physical and chemical properties of soils. The purely agricultural subject of soils and the engineering subjects of drainage and irrigation are obviously closely related in many respects. It would seem, therefore, that cases might frequently occur in which cooperation between the soils and agricultural engineering departments would be profitable in establishing fundamental hydraulic principles governing the movement and activities of water in soils as bases for drainage and irrigation studies.

FARM-SEWAGE DISPOSAL

Numerous attempts have been made from time to time at several of the experiment stations to meet the pressing demand for so-called practical information on the subject of farm-sewage disposal. A review of the attempts shows them to be generally lacking in the elements of advanced research. The importance of a consideration of the subject from its logical beginning through its scientific contacts to an ultimately practical solution for definite groups and classes of conditions has, however, been emphasized in some of these projects.

The Illinois station has undertaken a cooperative project designed to bring out some of the relations between sewage-tank dimensions and the chemical and biological changes taking place therein. The New Jersey stations have made an important preliminary contribution to the subject in the study by J. W. Thomson of the biology of sewage filters (*56*), and H. E. Murdock at the Montana station has engaged in a study of the factors governing the operation of both septic and Imhoff tanks (*57*). The Kansas Agricultural College has a project on the subject which is also well worthy of attention in that it proposes to develop a fundamental study lasting from 5 to 10 years. In this connection, preliminary studies by H. B. Walker (*58*) on flow characteristics of household sewage from the isolated home have shown that the flow assumptions sometimes made for the design of sewage tanks ranging from 30 to 75 gallons per person per day are too high.

A careful consideration of all the factors involved in the subject of farm-sewage disposal, with particular reference to the object to be accomplished by sewage-disposal measures, indicates the importance of first studying, analyzing, and classifying the conditions to be met by such measures. This was done in a tentative way by R. W. Trullinger, of the Office of Experiment Stations (*59*), but in a manner

sufficiently comprehensive to show the possibilities of such a procedure. The work of H. W. Riley at the New York Cornell station (*60, 61*), of J. R. Haswell at the Pennsylvania station (*62*), and of several of the State departments of health has shown that such a procedure is well worthy of consideration as a preliminary to undertaking studies on farm-sewage disposal.

MATERIALS OF CONSTRUCTION

Construction material is a subject which has developed from a minor miscellaneous matter into one of the most important branches of agricultural engineering; and its rise to such a position can be considered as a natural result of the developement of agricultural engineering as a whole, owing probably to the fact that it bears a close relation to all other branches of the subject.

A great deal of the work done at the experiment stations on materials of construction has been of a very general and apparently comparative or elementary nature. Some of it, however, has had very definite objectives.

Thus studies on the preservative treatment of posts and timbers used in farm structures have a very evident object in view which frequently takes many years to attain. The work at the Iowa station (*63, 64*), for instance, on the preservative treatment of farm timbers, which has been carried on for 16 years, has shown that the quick-growing nondurable Iowa woods can be successfully used for fence-post purposes after having been properly treated with creosote, and that durable fence-post woods, such as white cedar, can be made to last for a long period of years with little deterioration after creosote treatment.

Results of a similar nature have been obtained by J. C. Wooley at the Missouri station (*65*) and by A. K. Chittenden at the Michigan station (*66*). In addition, a nine-year study at the Iowa station of over 700 concrete fence posts of different types has indicated that four 0.25-inch square twisted reinforcement rods are necessary to develop maximum strength without the excessive use of steel (*67*).

An eleven year study of roofing materials at the Iowa station (*67,68*) has indicated the lower durability of materials with a high volatile content, and that a protective layer of mica, sand, or crushed stone has a beneficial influence upon durability. A thirteen year study of shingles at the Pennsylvania station has also yielded valuable data on shingle preservation (*69*).

In studies at the Minnesota station on the effect of organic decomposition products in soils of high vegetable content upon concrete draintile (*70*), Elliott showed that concrete tile always contain free alkali. This reacts with acid organic compounds from peat soils, producing gelatinous compounds which are soluble in water containing carbon dioxid. Therefore, concrete tile as at present made are likely to fail as drainage structures when used in peat soils in the presence of water.

Closely related to this work are the studies conducted by K. Steik at the Wyoming station on the effect of alkali upon Portland cement (*71, 72*). The results of these showed that the chief reacting substance in Portland cement is lime in the form of calcium hydroxid.

Cement set as well in solutions of alkali salts as in water, and magnesium chlorid had the greatest disintegrating effect. Sodium sulphate was more harmful than magnesium sulphate, and the presence of sodium chlorid in solutions of either increased their harmful effect upon cement, while the presence of sodium carbonate retarded it. The tensile strength of cement was the factor most affected by alkali solutions, decreasing most rapidly in all solutions, even when the compressive strength was increased. Waterproofing paints offered only temporary protection against alkali solutions. Obviously this work might be carried much further in the development of resisting processes.

The transmission of heat through wall materials is a matter of vital importance in farm-building design. In this connection G. A. Cumings, of the Colorado station, studied the factors governing the transmission of heat through commercial wall board (*73*), and found that the average coefficient of heat transmission varied from 0.73 B. T. U. per hour per square foot per degree Fahrenheit difference in temperature from beaver board to 1.01 for sheet rock wall board. These materials were found to be slightly inferior to common lath and plaster 0.5 inch thick and superior to wood in many cases of light construction.

These studies indicate lines and starting points for further study of the respective problems, and bring out the importance of securing effective cooperation in such studies, particularly where needed in the more technical phases of the work.

LAND CLEARING

Work on land clearing at the stations has developed rapidly during recent years; but it is still quite indefinite in nature and it is difficult in many cases to see wherein the principles of research might be applied in the solution of specific problems.

There are at least 13 distinct projects in land clearing at six different stations, most of which deal with comparisons of known or available methods and apparatus for land clearing and the cost thereof. The projects at the Wisconsin and Minnesota stations are among the more comprehensive in that they not only deal with stump and brush removal by explosives and machinery, but have involved the development of new types of plows and cultivating machinery adapted specifically to the breaking and cultivation of the cleared land.

For example, experiments by J. Swenehart and F. W. Duffee, of the Wisconsin station (*74*), on an improved bush-breaking plow indicated the necessity of redesigning and offsetting the beam to prevent the accumulation of roots and brush. Studies by Swenehart (*75*) on T. N. T. as a land-clearing explosive showed that this material is relatively very insensitive and difficult to detonate, but is quite resistant to such moisture as occurs under ordinary land-clearing conditions. It compared well with 20 per cent dynamite as a blasting explosive. Experiments by Swenehart on the use of picric acid as an agricultural explosive (*76*) resulted in the recommendation of the use of this material in open-air blasting work, provided its cost is less than that of other commercial explosives.

Work on engineering equipment for land clearing by Swenehart (*77*) resulted in mechanical methods and apparatus for removing and handling stumps, the development of which obviously involved an extensive consideration of fundamental physics and mechanics.

Studies by O. I. Bergh and A. H. Benton, of the Minnesota station, on the comparative values of different methods of land clearing (*78*) showed conclusively the advantage of pulling over dynamiting in stump removal, although shattering before pulling had a slight advantage over pulling alone. Forty per cent dynamite gave better results than 20 per cent as an explosive.

Studies by M. J. Thompson, of the Minnesota station, on forced versus delayed systems of clearing stump land (*79*) indicated the superiority of the delayed system.

Experiments by W. Rudolfs, of the New Jersey stations (*80*), demonstrated that sulphur is valueless for killing live stumps, but that rock salt when applied in proper amounts is quite effective.

H. D. Scudder, of the Oregon station (*81*), devised a new method of removing stumps by burning, which involves the use of a furnace, hood, draft pipe, and chimney. By means of these a hole is burned through the base of the stump, converting it into a stove, which eventually destroys itself. This method is especially adapted for the removal of the larger stumps.

The work of Nichols and E. C. Easter, of the Alabama station, has involved considerable work on the clearing of cut-over lands by blasting and other methods (*82, 83*). Apparently blasting is the favored method. In this connection it has been realized by these investigators that not enough is yet known of the factors which govern stump removal by explosives. The conditions of existence of stumps are apparently too variable to permit of an exact application of the principles of ballistics in determining explosive forces necessary for breaking taproots, lifting and inverting the stump, and breaking the lateral roots. However, an attempt has been made to arrive at this information in an indirect manner (*84*), and some fundamental factors have already been established relating to location, depth, and angle of bore hole, type, size, and manner of placing of charge, and other factors which influence the necessary explosive force. The purpose has been obviously to establish some of the requirements which explosives must meet in stump removal to serve somewhat as a guide to explosive manufacturers. This constitutes a distinct departure from the usual comparative testing method and seems to indicate wherein research methods may be applied in some features of the land-clearing problem.

SOIL EROSION

Soil erosion and methods for its prevention offer considerable opportunity for fundamental study, particularly in the South Atlantic and Gulf Coast States. Much of the work hitherto undertaken on this subject at the stations has consisted mainly of comparative tests of terraces of different shapes, sizes, and grades. It is believed that this work should start with a consideration of the factors governing the erosion of soil by water, the influence of different treatments on these factors, and the amount of soil removed by running water under known conditions. Studies could then be intelligently undertaken to develop methods of prevention of erosion.

It is realized that, when dealing with so variable a factor as soil, it is difficult to apply intelligently any established method of research procedure in the solution of the erosion problem. However, a beginning has been made by M. F. Miller, F. L. Duley, and O. B. Price at the Missouri station (*85*, *86*) in studies on water absorption, run-off, percolation, evaporation, and capillary water movement in relation to soil erosion under field conditions. These have already brought out some rather general relations between erosion and types of tillage and nature of vegetation, and have indicated the rapid erosive tendencies of scraped soils and the superiority of a crop-rotation system over continuous grain cropping in this respect. It is believed that elaborations or modifications of this method of work to meet the specific soil, climatic, and farming conditions of other States might aid materially in placing the development of methods of soil erosion prevention upon a more stable basis.

REFERENCES

(1) Indiana Sta. Rpt. 1920, p. 24.
(2) Relation of lug equipment to traction. R. U. Blasingame. Amer. Soc. Agr. Engin. Trans., 15 (1921), pp. 171–177.
(3) Factors influencing the draft of plows. E. V. Collins. Amer. Soc. Agr. Engin. Trans., 14 (1920), pp. 39–55.
(4) Iowa Sta. Rpt. 1921, p. 9.
(5) Iowa Sta. Rpt. 1922, p. 8.
(6) Influence of speed upon the draft of plow. J. B. Davidson, L. J. Fletcher, and E. V. Collins. Amer. Soc. Agr. Engin. Trans., 13 (1919), pp. 69–77.
(7) Nebraska Sta. Rpt. 1921, p. 23.
(8) Missouri Sta. Bul. 179 (Rpt. 1920), p. 14. 1921.
(9) Missouri Sta. Bul. 189 (Rpt. 1921), p. 20.
(10) California Sta. Rpt. 1921, p. 99.
(11) California Sta. Rpt. 1922, p. 21.
(12) Iowa Sta. Rpt. 1921, p. 8.
(13) Iowa Sta. Rpt. 1922, p. 7.
(14) Report on disk harrow investigation. E. V. Collins, C. I. Gunness, A. E. Brandt, and E. J. Stirniman. Agr. Engin., 3 (1922), pp. 44, 45.
(15) A study of the plow bottom and its action upon the furrow slice. E. A. White. Jour. Agr. Research [U. S.], 12 (1918), pp. 149–182; rev. in Amer. Soc. Agr. Engin. Trans., 12 (1918), pp. 42–50.
(16) Agricultural engineering research in farm field equipment. M. L. Nichols. Agr. Engin., 5 (1924), pp. 35–38.
(17) California Sta. Rpt. 1923, p. 50.
(18) Tests of air cleaners for tractor engines. A. H. Hoffman. Agr. Engin., 3 (1922), p. 167.
(19) Efficiency of dust separation in air cleaners for internal-combustion engines. A. H. Hoffman. Agr. Engin., 4 (1923), pp. 89–95, 109–116.
(20) Dust and the tractor engine. A. H. Hoffman. California Sta. Bul. 362. 1923.
(21) A study of sidedraft and tractor hitches. A. H. Hoffman. California Sta. Bul. 349. 1922.
(22) Equalizers and hitches. E. A. White. Amer. Soc. Agr. Engin. Trans., 12 (1918), pp. 124–135.
(23) Iowa Sta. Rpt. 1920, p. 8.
(24) Testing the efficiency of silage cutters. F. W. Duffee. Agr. Engin., 5 (1924), pp. 3–6.
(25) Experiences in the first breaking of peat lands. G. R. B. Elliott and J. L. Larson. Agr. Engin., 4 (1923), pp. 83–88.
(26) The design of farm elevators. W. G. Kaiser and W. A. Foster. Agr. Engin., 2 (1921), pp. 51–56.
(27) Recent developments in farm buildings. F. C. Fenton and A. W. Clyde. Agr. Engin., 3 (1922), pp. 59–62.
(28) Tests of self-supporting barn roofs. A. W. Clyde. Agr. Engin., 4 (1923), pp. 107–109, 118.

(29) Tests of a masonry arch barn roof. A. W. Clyde and H. Giese. Agr. Engin. 5 (1924), pp. 30, 31.
(30) Modern silo construction. J. B. Davidson and M. L. King. Iowa Sta. Bul. 100. 1908.
(31) The Iowa silo. J. B. Davidson and M. L. King. Iowa Sta. Bul. 117. 1910.
(32) Modern silo construction. J. B. Davidson. Iowa Sta. Bul. 141. 1913.
(33) Silo construction. C. K. Shedd and W. A. Foster. Iowa Sta. Bul. 189. 1919.
(34) Iowa Sta. Rpt. 1918. p. 9.
(35) Pennsylvania Sta. Rpt. 1916, pp. 323–348.
(36) Iowa Sta. Rpt. 1922, pp. 7–10.
(37) Measuring silage and capacity of silos. L. W. Chase. Nebraska Sta. Circ. 1. 1917.
(38) Capacities of silos and weights of silage. C. H. Eckles, O. E. Reed, and J. B. Fitch. Missouri Sta. Bul. 164. 1919.
(39) Capacity of silos and weights of silage. C. H. Eckles, O. E. Reed, and J. B. Fitch. Kansas Sta. Bul. 222. 1919.
(40) Some fundamentals of stable ventilation. H. P. Armsby and M. Kriss. Jour. Agr. Research [U. S.], 21 (1921), pp. 343–368.
(41) Test of a fan system of ventilation for dairy barns. M. A. R. Kelley. Agr. Engin., 2 (1921), pp. 203–206.
(42) The design of outtake flues for stable ventilation. J. L. Strahan. Agr. Engin., 2 (1921) pp. 207–209.
(43) Factors influencing the design and operation of farm-building ventilation systems. M. A. R. Kelley. Agr. Engin., 3 (1922), pp. 150–154.
(44) Test of a hog-house ventilation system. M. A. R. Kelley. Agr. Engin., 3 (1922), pp. 164–167.
(45) Recent tests of ventilation systems in farm buildings. M. A. R. Kelley. Agr. Engin., 5 (1924), pp. 7, 8.
(46) The ventilation of potato warehouses. F. E. Fogle. Michigan Sta. Quart. Bul., vol. 5, No. 1, pp. 20–25. 1922.
(47) Sweet potato storage in Delaware. T. F. Manns. Delaware Sta. Bul. 127. 1920.
(48) Missouri Sta. Bul. 189 (Rpt. 1921), p. 54.
(49) Tile drainage investigations in North Carolina. H. M. Lynde. Agr. Engin., 2 (1921), pp. 133–135.
(50) Special features of the drainage of irrigated lands. W. W. Weir. Agr. Engin., 3 (1922), pp. 182–186.
(51) Water-holding capacity of irrigated soils. O. W. Israelsen and F. L. West. Utah Sta. Bul. 183. 1922.
(52) Washington Sta. Bul. 175 (Rpt. 1922), p. 54.
(53) The net duty of water in Sevier valley. O. W. Israelsen and L. M. Winsor, Utah Sta. Bul. 182. 1922.
(54) California Sta. Rpt. 1921, p. 20.
(55) California Sta. Rpt. 1922, p. 104.
(56) A study of the biology of the sprinkling sewage filter. J. W. Thomson. New Jersey Sta. Bul. 352. 1921.
(57) The septic tank—A method of sewage disposal for the isolated home. H. E. Murdock. Montana Sta. Bul. 137. 1920.
(58) Flow characteristics of household sewage from the isolated home. H. B. Walker. Agr. Engin., 4 (1923), pp. 159, 160.
(59) Septic tanks in relation to farm sewage disposal. R. W. Trullinger. Amer. Soc. Agr. Engin. Trans., 11 (1917), pp. 67–76.
(60) Farm-sewage disposal devices. H. W. Riley. Amer. Soc. Agr. Engin. Trans., 15 (1921), pp. 131–135.
(61) Sewage disposal for rural homes. H. W. Riley and J. C. McCurdy. New York State Col. Agr., Cornell Univ. Ext. Bul. 48. 1923.
(62) Septic tanks for the farm. J. R. Haswell. Pennsylvania State Col. Ext. Circ. 89. 1921.
(63) Iowa Sta. Rpt. 1920, p. 49.
(64) Iowa Sta. Rpt. 1921, p. 48.
(65) The durability of fence posts. J. C. Wooley. Missouri Sta. Circ. 108. 1922.
(66) Durability of fence posts. A. K. Chittenden. Michigan Sta. Quart. Bul., vol. 5, No. 3, pp. 137–139. 1923.
(67) Iowa Sta. Rpt. 1922, p. 9.
(68) Iowa Sta. Rpt. 1920, p. 7.

(69) Pennsylvania Sta. Bul. 170 (Bien. Rpt. 1920–21), p. 26. 1922.
(70) Effect of organic decomposition products from high vegetable content soils upon concrete drain tile. G. R. B. Elliott. Jour. Agr. Research [U. S.], 24 (1923), pp. 471–500.
(71) The effect of alkali on Portland cement. K. Steik. Wyoming Sta. Bul. 113. 1917.
(72) The effect of alkali upon Portland cement, II. K. Steik. Wyoming Sta. Bul. 122. 1919.
(73) Heat transmission of commercial wall board. G. A. Cumings. Colorado Sta. Bul. 282. 1923.
(74) Wisconsin Sta. Bul. 352 (Rpt. 1922), pp. 113–116. 1923.
(75) Wisconsin Sta. Bul. 319 (Rpt. 1919), pp. 38, 39. 1920.
(76) Picric acid as an agricultural explosive. J. Swenehart. Agr. Engin., 2 (1921), pp. 246–248.
(77) New engineering developments in land clearing. J. Swenehart. Agr. Engin., 3 (1922), pp. 63–66.
(78) Minnesota Sta., Rpt. Grand Rapids Substa., 1915–1919, pp. 59–70.
(79) Forced v. delayed systems of clearing stump land. M. J. Thompson. Minnesota Sta. Bul. 189. 1920.
(80) Experiments on the value of common rock salt and sulphur for killing live stumps. W. Rudolfs. Soil Sci., 9 (1920), pp. 181–189.
(81) Stump-land reclamation in Oregon. H. D. Scudder. Oregon Sta. Bul. 195. 1922.
(82) Land clearing. M. L. Nichols. Alabama Col. Sta. Circ. 44. 1921.
(83) Clearing cut-over lands in Baldwin County [Ala.]. E. C. Easter and M. L. Nichols. Alabama Col. Sta. Circ. 45. 1922.
(84) (Not yet published.)
(85) Missouri Sta. Bul. 189 (Rpt. 1921), pp. 50–55, 57.
(86) Missouri Sta. Bul. 197 (Rpt. 1922), pp. 81–89.

RANGE INVESTIGATIONS BY THE EXPERIMENT STATIONS

By W. H. Beal, G. Haines, W. A. Hooker, and J. I. Schulte

Various features of the range industry have for many years received attention by the experiment stations in the States where the industry is of particular importance.

Several of the stations have featured range studies prominently. This is especially true of the Arizona station, whose studies date almost from its establishment and cover practically all phases of the subject; the New Mexico station, which has led in the study of the nutritive value and use of range plants for feed, food, and other purposes; the Wyoming station, which has made the composition of range grasses, supplementary feeding, poisonous plants, and diseases of range stock prominent subjects of investigation for many years; the Nevada station, which, among the first to study range plants systematically, established a department of range management in 1915 and now makes range agriculture the leading feature of its work; and the Texas station, which established a well-equipped range station at Sonora in 1916 and also has a division of farm and ranch economics which, among other things, gives attention to range management and the economic and sociological features of ranch life. The Colorado station has undertaken rather elaborate experiments to determine the benefits of deferred and rotative grazing.

The stations have cooperated with the United States Department of Agriculture in some important features of range work.

Principal lines of work.--The range studies of the stations have covered a wide and diverse field, as the following list shows:

Alaska: Range forage.
Arizona: Carrying capacity; range improvement; emergency use of range plants; poisonous plants; rodent injury.
California: Range vegetation; nutritive value of range forage; diseases.
Colorado: Range improvement; revegetation of ranges; supplementary crops; poisonous plants
Guam: Range plants.
Hawaii: Range plants and management.
Idaho: Range management; poisonous plants.
Kansas: Range grasses; range management.
Montana: Range vegetation; grazing experiments; poisonous plants; diseases.
Nebraska: Supplementary feeds and feeding.
Nevada: Range plants; revegetation; poisonous plants; diseases; range management; improving range sheep; protection of range lambs; feeding and finishing of range sheep.
New Mexico: Range vegetation; adaptation of plants to ranges; nutritive value of range plants; poisonous plants; supplementary feeding; range management.
North Dakota: Range plants; range renewal; carrying capacity; diseases.
Oklahoma: Diseases.
Oregon: Range vegetation; poisonous plants; supplementary feeding.
Texas: Range plants; improvement of range sheep; diseases; economic and sociological aspects of ranch life.
Utah: Range surveys and renewal; supplementary feeding.
Washington: Range vegetation; diseases; range management.
Wyoming: Composition of range grasses; poisonous plants; diseases; factors affecting wool; supplementary feeding.

Range vegetation.—Several of the experiment stations have made systematic studies of the vegetation of typical range areas. These studies have dealt especially with such matters as the character, distribution, and relative forage value of range plants and the conditions of their depletion and renewal.

Extensive studies of this kind on the range plants of certain parts of Washington have been reported by the Washington station (*93, 95, 96*)[4], of Montana by the Montana station (*27, 30*), of New Mexico by the New Mexico station (*60, 62*), and of the sheep ranges of Nevada by the Nevada station (*37, 38*). The Arizona station (*3, 4*) has done extensive work on range vegetation and especially on the value of cacti as a range forage. The Oregon station in cooperation with the United States Department of Agriculture[5] has studied the important range plants of the Wallowa National Forest.

The Hawaii station (*23, 24*) and the Guam station (*22*) have reported upon the principal range grasses and forage plants of those islands and the means of improving the range vegetation.

These studies have shown the widely varying character of the vegetation of the ranges and have furnished the basis for important recommendations regarding range management.

Carrying capacity of ranges.—Such observations as have been made on the carrying capacity of ranges show that conditions vary so widely and change so rapidly that it is difficult to generalize or to lay down rules which are universally or permanently applicable. Some of the conclusions reached by the stations which have made most study of the subject are as follows:

The Arizona station (*3*), cooperating with the United States Department of Agriculture, found that much depleted ranges recovered faster when pastured judiciously with approximately all the cattle they could carry than when not grazed at all. The best lands improved under stocking at the rate of one bovine to 20 acres. Overgrazing invariably resulted in the appearance of inferior plants and lessened carrying capacity.

In experiments at Scottsbluff, Nebr. (*36*), 800 acres of dry land range pasture carried 82 steers for 142 days from June 3.

The Nevada station (*49*) found that 2.33 acres per sheep was required for 100 days' pasture under the usual permanent-camp method of grazing, the required acreage being reduced to 1.82 acres by using one-night camps.

The average grazing capacity of New Mexico ranges was found by the station in 1908 (*60*) to be about 35 acres per head of cattle, but varied widely.

In tests of the carrying capacity of native range grasses by the North Dakota station (*74, 77, 80*) it was found that 3 acres furnished pasturage for a steer for 90 days, 5 acres for 135 days, and over 5 acres throughout the season, 150 days. Incidentally the same station (*76*) observed that on 30 acres of fair pasture a steer traveled $1\frac{5}{8}$ miles per day and on 100 acres $3\frac{1}{6}$ miles for food and water.

The Washington station (*93, 96*) has reported upon the conditions which affect the carrying capacity of the grazing areas of Wenaha

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[4] Italic numbers in parentheses refer to References, p. 123.
[5] U. S. Dept. Agr. Dept. Bul. 545, Important range plants, their life history and forage value. A. W. Sampson. 1917.

National Forest and of the ranges of central Washington, and the California station (*15*) on the gain or loss in weight of cattle of different classes on summer mountain range.

Composition and nutritive value of range plants.—Several of the experiment stations have made studies of the nutritive value of some of the more important range plants. with reference especially to their use as emergency feeds, but also as human food and for other purposes.

Analyses of a number of representative range plants have been reported by the Arizona station (*8, 10*), which has studied particularly the value of cacti (*4*) and of yucca (*6, 9*) as emergency feeds. The station has shown that although these plants are not well-balanced feeds, being deficient especially in protein and fat, they have served to save thousands of range cattle from starvation in time of shortage of other forage.

The earlier growth of range plants was found by the California station (*16*) to be more nutritious than the later. This station has also emphasized the importance of the content of mineral matter in the plants.

The composition, digestibility, and feeding value of cacti, soap weed (*Yucca elata*), chamiza (*Atriplex canescens*), and other characteristic range plants have been the subjects of particularly thorough investigation by the New Mexico station (*59, 61, 63, 64, 67*). The station has shown that these plants as a rule have considerable feeding value but may be objectionable as exclusive feeds. It was found that range cows could be maintained for long periods on soap-weed stems alone, but that the addition of a concentrate like cottonseed meal was of decided advantage because the soap weed is very deficient in protein and fat. No indications of poisonous effects were observed and normal calves were produced by cows fed on the soap weed. Similar results were obtained in feeding sotol heads. Chamiza was found to be of value as a feed, but gave best results when fed in combination with corn stover and other roughages high in fiber. Long-continued feeding on chamiza alone was found to result in digestive disturbances and other troubles, although no specific poisonous effects were observed.

Russian thistle has been shown by the North Dakota station (*73*) to be very rich in mineral matter, especially potash, and highy cathartic when fed exclusively.

Studies by the Texas station (*88, 89*) of the composition and feeding value of several common range plants of the Southwest, including soap weed, Spanish dagger (*Yucca macrocarpa*), bear grass (*Y. glauca*), and sotol (*Dasylirion* sp.), have shown that some of these have emergency value.

Studies by the Colorado station (*17*) of the composition and digestibility of Australian saltbush showed this plant to have considerable feeding value.

The July cutting of prairie hay was found by the North Dakota station (*78*) to be from 12 to 15 per cent more digestible than hay cut in early spring or October.

The study of the composition, digestibility, and comparative feeding value of Wyoming range grasses and native hay has been given much attention by the Wyoming station (*100, 101, 102, 103, 104, 105, 110*) and many of the grasses have been shown to be highly nutritious.

Analyses of several of the more common forage plants of the grazing regions in southern Alaska, particularly blue top (*Calamagrostis langsdorfii*), sedge (*Carex cryptocarpa*), and beech grass (*Elymus mollis*), have been reported by the Alaska stations (*1*, *2*).

Supplementary feeding and care.—The study of emergency and supplementary feeds to tide over periods of shortage, to carry range animals through the winter, and to fatten them for the market has been an important feature of the work of many of the experiment stations.

Sorghum silage and cottonseed meal were found by the Arizona station (*7*) to be satisfactory supplementary feeds for range cattle during periods of drought. The same station (*5*) found alfalfa and sorghum silage efficient feeds for fattening range steers for market.

The addition of from 5 to 10 pounds of native hay to the ration of range cows during winter was found by the Montana station (*34*) to be very advantageous in keeping the animals in good breeding condition.

To prevent the extermination of white sage (*Eurotia lanata*), the most important winter forage plant of the Nevada ranges, the Nevada station (*51*) recommends that sheep grazing on such ranges be given a supplementary feeding of cottonseed cake.

In attempts to utilize Russian thistle as silage in a supplementary and emergency feed, the New Mexico station (*68*) found that the silage had a disagreeable odor when fresh and deteriorated rapidly on exposure to the air. To provide the proper fermentation, corn meal was mixed with the Russian thistle in the proportion of 1 part to 100, the result being a more satisfactory silage, on which range cows maintained their weight for 20 days. This station (*65*, *66*, *70*) has also shown the emergency feeding value of tornillo, mesquite, and pinto beans, and has given considerable attention to supplementing the range with dry farm crops as well as to the utilization of feed by range steers of different ages.

By placing range cattle on corn fodder at the close of the grazing season, the North Dakota station (*76*) secured a daily gain of 2.5 pounds per head and 194 pounds per acre of corn fodder used.

The winter and summer gains of range steers wintered on roughages, the relative advantage of shelter versus feeding in the open, and, in general, different methods of winter feeding and protection have been compared by the Oregon station (*82*, *83*).

Winter feeding and protection of range animals and the use of supplementary feeds have been given particular attention by the Wyoming station (*110*, *112*, *119*, *123*). This station has reported experiments in which steers made an average gain of 0.6 pound a day on native hay alone during a period of 70 days and 1.5 pounds when oat and pea silage was added to the ration. A comparison of the gains made by steers on the range and in dry lot during the winter showed that, although the range steers made practically no gain during the winter, they were nearly equal in weight with the others after summer pasturage.

Poisonous plants.—Poisonous plants are the cause of serious losses of stock on the ranges. The Wyoming station (*117*) estimates that such losses amount on the average to about 3 per cent in Wyoming, being greatly increased when wholesome forage is scarce or the stock hungry or in poor condition. The Nevada station (*52*, *57*) reports larger

losses of sheep from this cause on Nevada ranges than from all recognized diseases, the losses being increased by overstocking.

The Montana station (*26, 28, 33*) was among the first to investigate this matter, but the Wyoming and Nevada stations have probably pursued it further than any others. These stations have led especially in chemical studies and physiological tests of the toxic principles of the plants, in actual feeding experiments with the plants, and in investigation of remedial and protective measures.

Investigations of the poisonous properties of three species of larkspur (*Delphinium barbeyi, D. glaucescens,, and D. geyeri*) by the Wyoming station (*113, 117*) indicate that the plains larkspur (*D. geyeri*) is the most common and most deadly species in Wyoming and kills more cattle than all the other poisonous plants of the State. It is especially dangerous in its early stages of growth. It was found that "poisoning is due to a definite active principle occurring mostly in the leaves." Other species are also deadly but are less common and hence cause smaller losses. In feeding experiments with steers the Nevada station (*42*) found 2.5 to 3 per cent of the body weight to be a fatal dose of larkspur. Sheep are apparently not affected and horses seldom eat enough to do them harm.

The Nevada station (*42*) finds the lupines poisonous to all classes of stock, but especially to sheep feeding on the pods. Few horses and cattle are poisoned. From one-fourth to one-half pound of the seed produced acute poisoning or death in sheep. The silvery lupine (*Lupinus argenteus*) is reported by the Wyoming station (*117*) to be the most common and most deadly of the lupines. The seeds and pods are the most poisonous parts and drying does not destroy the poison. Poisonous alkaloids were isolated from this plant and studied chemically and physiologically by the Wyoming station (*116*).

The poisonous properties of the water hemlock have been investigated to some extent by the Wyoming station (*117*) but particularly by the Nevada station (*40, 46*). Chemical studies and feeding experiments by the latter showed that the roots of *Cicuta occidentalis* contain a noncrystalline substance having the formula $C_{19}N_{26}O_3$, for which the name cicutoxin is proposed and which is highly poisonous to cattle, sheep, and horses. Old tubers are especially deadly, but young shoots and tops are also poisonous. In feeding experiments at the Nevada station (*46*) about three-fourths pound of old tubers was found to kill a cow, one-half pound a horse, and one-eighth pound a sheep. The poison is a violent one and acts so quickly that there is little time to administer antidotes. Losses due to this plant are especially heavy in case of cattle.

All parts of death camas at every stage of its growth are, according to the Wyoming and Nevada stations, poisonous to all classes of stock but especially to half-starved sheep on overgrazed ranges. The Wyoming station (*106, 108, 117*) has isolated the alkaloidal poison zygadenin from *Zygadenus intermedius* and studied its properties. The Nevada station obtained a similar but apparently not identical alkaloid from *Z. paniculatus*, which killed rabbits in 0.35-gram doses. This station (*47*) found that one-fourth to one-half pound of *Z. paniculatus* made sheep sick, but 3 pounds or more was required to kill them. Three-eighths to 2 pounds made young cattle sick but did not kill them.

The Nevada station (*42*) states that, though the locos are widely distributed in that State, they do not cause serious losses and these are largely confined to sheep and horses. The Wyoming station (*117*) reports that the white loco is widely distributed in that State but does not cause losses comparable with those reported from other States. The purple loco is not so widely distributed. Losses due to locos are confined largely to horses.

Woody aster (*Xylorrhiza parryi*) is reported by the Wyoming station (*117*) to be the cause of large losses of sheep on Wyoming ranges but these losses have been reduced by better range management. The poisonous principle of the plant has been isolated and studied chemically and physiologically by the station (*107*, *114*). The plant appears to vary in toxicity at different stages of growth, being most poisonous during early growth, but at no time free from toxicity.

That arrow grass (*Triglochin maritima*), in both the green and the dry condition, is under certain conditions poisonous to sheep and cattle was shown by experiments at the Nevada station (*44*). The poisonous principle appears to be a cyanogenetic substance which breaks up in the animal's stomach, liberating sufficient hydrocyanic acid to be quickly fatal, the hay being more deadly than the green plant.

The Nevada station (*45*) found the green leaves, pods, and seeds of milkweeds (*Asclepias mexicana* and *A. speciosa*) to be poisonous to sheep and cattle, the seeds being highly so. Plants dried naturally on the range retained little of their poisonous properties. The toxic principle of the narrow-leaved milkweed (*A. mexicana*), which is far more deadly than the broad-leaved species, was extracted and studied chemically and toxicologically by the Nevada station. The Wyoming station (*117*) reports the broad-leaved milkweed (*A. speciosa*) to be one of the lesser poisonous plants of that State. The Colorado station (*18*, *19*, *20*) reports serious losses of sheep due to eating the whorled milkweed (*A. galioides*). The plant appears to be poisonous at all stages and does not lose its toxicity by drying.

The milk vetch (*Astragalus bisulcatus*) is reported by the Wyoming station (*117*) to be poisonous to sheep and cattle, but ordinarily not particularly dangerous because of its coarse appearance and offensive odor, which repel animals. The Wyoming station (*111*) has obtained a crystalline water-soluble poisonous principle from all parts of the plant which reacts chemically as a glucosid.

In feeding experiments at the Nevada station (*54*) rabbit brush (*Tetradymia glabrata*) was shown to have a cumulative toxic effect which is finally fatal, especially to sheep feeding on it exclusively for some time.

Goldenrod (*Solidago spectabilis* and *S. concinna*), both fresh and dry, is reported by the Nevada station (*42*) to be poisonous to sheep 1.1 pounds of the green plants proving fatal. No poisonous principles were found in the plant and it is suggested that the reported injury may be due to its high content of ash and especially of potash.

Psoralea (*P. tenuiflora*) is stated by the Wyoming station (*117*) to be undoubtedly poisonous, but because of its bitter taste it is seldom eaten.

The Wyoming station (*117*) states that "while the aconites are poisonous plants, it is pretty definitely settled that they do not poison range stock." The plants are fatally poisonous to sheep and horses

but cattle are apparently not susceptible. *Aconitum columbianum* was the most poisonous of the species studied by the station.

The Nevada station (*54*) has obtained from saltbush (*Atriplex canescens*) a number of poisonous saponins, the activity of which depends largely upon the time of year when the plants were gathered.

The Nevada station (*42*) states that sheep are the only animals known to be poisoned by false hellebore, which is not widely or abundantly distributed on the ranges of the State.

Losses of range stock occur from time to time as a result of eating certain nonpoisonous plants, as, for example, foxtail (*Hordeum jubatum*). The Nevada station (*43*) found the eating of the bearded heads of this plant particularly fatal to lambing ewes and lambs. In the fatal cases observed the animals were blinded or their mouths were made so sore that they either died of starvation or else fell easy victims to common disease. The injury was due to the lodgment of the barbed awns of the grass in the delicate tissues and membranes of the ear, eye, or mouth.

A comprehensive summary, with illustrations, some colored, of information regarding the principal stock-poisoning plants of Oregon, with an extensive bibliography, has been published by the Oregon station (*84*). A similar bulletin was published by the Nevada station (*42*), especially for the benefit of sheep herders; and, since many of these herders are Basques, a Spanish edition of the bulletin was also issued. Information regarding various plants poisonous to range stock is recorded by the Idaho station (*25*) and the Hawaii station (*23*).

Unusual losses of stock from poisonous plant in 1920 were reported by the Arizona station (*11*), the most important plants mentioned as involved including spreading loco (*Aragallus nothoxus*), Thurber's loco (*Astragalus thurberi*), hairy loco (*A. bigelowii*), tall loco (*A. diphysus* and *A. diphysus macdougali*), purple loco (*Aragallus lamberti*), blue larkspur (*Delphinium scaposum*), prairie larkspur (*D. camporum*), death camas (*Zygadenus elegans*,) and rayless goldenrod or burrow weed (*Bigelowia coronopifolia*).

Diseases affecting range stock.—Among the more important diseases especially affecting range livestock which have been investigated by the experiment stations are tuberculosis, abortion, infectious anemia, chronic pneumonia ("lunger disease"), necrobacillosis, ictero-hemoglobinuria, red water, goiter, and internal parasites. Various other diseases affecting cattle and sheep under range conditions have also been investigated with results of local value.

The intradermic test for tuberculosis has been developed and applied to range cattle by the California station (*12*) with marked success. Water holes were found to be an important source of infection, the organisms retaining their vitality in these holes for about a year. The application of the intradermic test to range cattle is also reported by the Montana station (*31*). The Wyoming station (*122, 129*) in a study of avian tuberculosis in relation to range cattle found that cattle can be infected with avian tuberculosis when injected beneath the skin and that the intradermic test is the most reliable means of detecting the disease in cattle.

Infectious abortion on the ranges has been the subject of special study by the California station (*13*). The Montana station (*29*) has reported work on this subject and has undertaken the study of the relation of contamination of the water supply to abortion. Tests by

the Wyoming station (*124, 129*) show that a large percentage of range cattle are infected with *Bacillus abortus*. Promising tests of living culture abortion vaccine as an immunizing agent are in progress at this station, and tests of the isolation method of control at this station and at the Oregon station (*85, 86*) with promise of success if practiced with extreme care.

Swamp fever, or infectious anemia of horses, is a widespread disease which has been investigated by several of the experiment stations in the range country, particularly those of North Dakota (*72, 75, 79*), Wyoming (*121, 130*), Nevada (*39*), and Texas (*87, 91, 92*). The specific cause of the disease appears to be uncertain and no cure has been found. The extreme persistence of the disease has been strikingly demonstrated, especially by the North Dakota station (*79*). Some evidence has been secured that the disease is transmitted by certain biting flies, notably the stable fly (*Stomoxys calcitrans*) and the horsefly (*Tabanus septentrionalis*).

The so-called "lunger disease" (progressive pneumonia) of sheep has been given much attention by the Montana station (*35*), and although no progress has been made toward control of the disease it is claimed to have been definitely established "that under ordinary range management no 'lunger' sheep ever recover or even improve in condition, that 'lungers' in the ewe band in the fall will not live through the lambing time, and that those with 'lunger' disease in the spring, if sent to summer range, will die before fall." The causal organism has been isolated.

Necrobacillosis, which is quite prevalent and causes considerable losses on ranges, is being studied by the Wyoming station (*128*), which finds that there are different strains of the causal organism, varying in virulence and morphological characters. Immunity has been produced in rabbits by inoculation with virulent material (*125*). Serums have proved unsatisfactory (*126*). The Montana station has also studied the same disease (*35*), showing the various forms in which this disease manifests itself and suggesting preventive measures.

An obscure hemorrhagic disease (ictero-hemoglobinuria) of range cattle has been studied by the Nevada and Wyoming stations. The Nevada station (*56, 58*) has shown the disease to be distinct from anthrax and hemorrhagic septicemia, with which it was at first confused. Tests showed that the disease may be caused by *Bacillus welchii*, probably in combination with other bacteria. The disease can be cured in the early stages by serum treatment. When it has reached the bloody urine and feces stage no treatment is effective. Vaccination was tested with negative results.

Studies of bovine red water (cystic hematuria) by the Washington station (*94, 98*) indicated that the disease is due to oxalic acid in the feed. The disease is generally fatal.

Investigations by the Montana (*32*), Washington (*97*), and Wisconsin (*99*) stations, extending over a number of years, have shown that hyperplastic goiter is enzootic among all species of domestic animals in certain so-called goitrous regions, being especially prevalent in parts of Washington, Montana, and British Columbia. Iodin appears to be a specific for the trouble.

The life cycles and means of control of various parasites of range sheep, including *Moniezia expansa*, *Thysanosoma actinioides*, and *Sarcocystis tenella*, have been studied by the Wyoming station (*109,*

115, 127). In case of the latter the conditions of infection appear to conform best to the theory of an infective intestinal stage, and control measures based on protection against contaminated food are suggested. The effect of limited grazing on the degree of infection is being studied.

Internal parasites of range stock have also been studied by the Oklahoma station (*81*), Texas station (*91*), and others.

Horseflies, particularly *Tabanus phænops*, which cause great annoyance to cattle on ranges in Nevada and California, have been studied by the Nevada station (*48*). The annoyance is increased by the presence of the horn fly and the common stable fly. Drainage of wet meadows where the flies breed followed by the planting of alfalfa is proposed as the only practical means of control.

Range management.—Some phase or phases of range management have been studied by practically every station in the range country. Especially notable work along this line has been done by the experiment stations in Arizona, California, Colorado, Nevada, New Mexico, Oregon, Texas, Washington, and Wyoming, and this work has indicated various means of improving range practice.

The Arizona station (*3*) was one of the first to study the matter systematically, much of its work being done in cooperation with the United States Department of Agriculture. Finding overstocking and overgrazing to be the chief cause of depleted ranges, this station has advocated, among other things, moderate stocking, rotative grazing, leasing and fencing, Government control, and supplementary feeding. As a result of its studies on the possibilities of revegetation and increasing the carrying capacity of the ranges, the Arizona station has suggested for this purpose the development of the use of certain browsing plants, protected inclosures, and storm-water embankments to distribute and utilize the scanty rainfall to better advantage.

The California station (*14*), as a result of its studies, advocates deferred grazing, cooperative grazing of small flocks in the national forests, and supplementary (winter) feeding to meet the problems of depleted ranges.

The Colorado station (*21*) has studied the grazing of ranges under different methods of management, to see whether the range can be built up while still being grazed, particular attention being given to the effects of overstocking on the range vegetation.

The value of one-night camps as a means of protection against range depletion has been demonstrated by the Nevada station (*37, 38, 41, 49*). The station has also called attention to the advantages of deferred and rotative grazing and of frequent and well-distributed watering places. This station (*50*) has given particular attention to the possibility of reestablishing the white sage (*Eurotia lanata*) on ranges. As a result of its work on revegetation in general this station concludes (*53, 55*) that it is impossible to revegetate or increase the carrying capacity of the open unfenced range. The question of improving range sheep by the use of better bucks and of reducing losses by supplementary feeding and by providing shelter and other means of protection of lambing ewes and lambs is the subject of special study by the Nevada station (*55*).

The New Mexico station (*60, 71*) has studied the conditions determining the carrying capacity of ranges and has made various suggestions and recommendations regarding the rational management and

control of the public grazing lands. Among these are Government control of the grazing lands, rotative grazing, supplementary feeding of range stock, regulation of breeding, use of better bulls, more frequent drinking places, and more frequent and liberal salting.

The Oregon station (*84*) considers rotative grazing one of the most practical means of protection against poisonous plants.

The Texas station, in addition to studying questions relating to the improvement of range stock, has published the results of an exhaustive study (*90*) dealing with ranching as a productive rather than an exploitive industry, utilizing lands largely unsuited to production of cultivated crops and having in mind the permanent use of the land.

The Washington station (*93*, *95*, *96*), after having investigated various features of range management, has advocated, as means of protection of the range, fencing and moderate and rotative grazing. It also recommends the leasing of grazing lands, as this tends to eliminate injurious competition and overgrazing. The station reached the conclusion that well-managed (rotative) sheep grazing has no bad effect on the reproduction of forests or of grazing plants.

The Wyoming station (*117*) has studied methods of reseeding and improving range vegetation, and emphasizes especially the advantages of rotative grazing, use of one-night camps, avoidance of poisonous plants, and frequent and liberal salting. This station has also studied conditions affecting the quality of wool of range sheep and suggested means of bettering it. Sufficient variation was found in fleeces of range sheep to warrant culling, especially in case of fine-wooled sheep (*118*). Exposure to the weather was found to cause rapid and pronounced deterioration of the wool of fine-wooled open-fleeced sheep (*120*). Sunlight and alkali appeared to be of little importance as compared with other elements of weathering.

The question of the practicability of eradication of poisonous plants from ranges has been studied by some of the stations without very conclusive results. It appears, however, that dependence must be placed largely upon avoidance and preventive measures rather than upon eradication on any extensive scale.

Recognizing that the control of rodents on ranges is of increasing importance, the Arizona station, cooperating with the United States Department of Agriculture, undertook a study of the habits, injury, and means of eradication, especially of the jack rabbit and the kangaroo rat. A report on the latter has been issued [6] which indicates efficient means of control.

Summary.—The foregoing review shows that the work of stations on range problems has covered a wide field. The stations have done much to determine the character of the vegetation and the carrying capacity of ranges, the causes and means of prevention of deterioration, the nutritive value and uses of different kinds of range plants, and ways of promoting the growth of the better kinds of plants. They have also contributed much to efficient methods of supplementary feeding and finishing of range animals, increased our knowledge of poisonous plants and diseases which particularly affect range animals, and made important contributions to the complex problem of range management.

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[6] U. S. Dept. Agr. Dept. Bul. 1091. Life history of the kangaroo rat (*Dipodomys spectabilis spectabilis*).

The work points especially to the need of better control of the ranges, more restricted and judicious grazing, and better supplementary feeding and care of range animals. It is along the lines of supplementary feeding and care that some of the most important and useful work of the stations is being developed.

REFERENCES

(1) A report to Congress on agriculture in Alaska. W. H. Evans et al. Office of Experiment Stations Bul. 48, p. 13. 1898.
(2) Alaska Stas. Rpt. 1917, p. 77.
(3) The grazing ranges of Arizona. J. J. Thornber. Arizona Sta. Bul. 65. 1910.
(4) Native cacti as emergency forage plants, J. J. Thornber; Nutritive value of cholla fruit, A. E. Vinson. Arizona Sta. Bul. 67. 1911.
(5) Fattening native steers for market, 1920. R. H. Williams. Arizona Sta. Bul. 91. 1920.
(6) Feeding yucca to starving cattle. R. H. Williams. Arizona Agr. Col. Ext. Circ. 21. 1918.
(7) Arizona Sta. Rpt. 1917, p. 469.
(8) Arizona Sta. Rpt. 1917, p. 477.
(9) Arizona Sta. Rpt. 1918, p. 324.
(10) Arizona Sta. Rpt. 1919, p. 411.
(11) Arizona Sta. Rpt. 1920, p. 455.
(12) The intradermal test for tuberculosis in cattle and hogs. C. M. Haring and R. M. Bell. California Sta. Bul. 243. 1914.
(13) Bovine infectious abortion and associated diseases of cattle and new-born calves. G. H. Hart, J. Traum, and F. M. Hayes. California Sta. Bul. 353. 1923.
(14) California Sta. Rpt. 1921, p. 183.
(15) California Sta. Rpt. 1922, p. 54.
(16) California Sta. Rpt. 1922, p. 111.
(17) The Australian saltbush: Its composition and digestibility. Notes on Russian thistle. W. P. Headden. Colorado Sta. Bul. 135. 1908.
(18) A new poisonous plant, the whorled milkweed (*Asclepias verticillata*). G. H. Glover, I. E. Newsom, and W. W. Robbins. Colorado Sta. Bul. 246. 1918.
(19) Whorled milkweed, the worst stock-poisoning plant in Colorado. W. L. May. Colorado Sta. Bul. 255. 1920.
(20) Control of the whorled milkweed in Colorado. W. L. May. Colorado Sta. Bul. 285. 1923.
(21) Colorado Sta. Rpt. 1921, p. 15.
(22) Guam Sta. Rpt. 1913, p. 15.
(23) Grasses and forage plants of Hawaii. C. K. McClelland. Hawaii Sta. Bul. 36. 1915.
(24) Hawaii Sta. Rpt. 1912, p. 78.
(25) Some poisonous plants of Idaho, F. W. Gail; Some suggested remedies, A. R. Hahner. Idaho Sta. Bul. 86. 1916.
(26) Larkspur poisoning of sheep. E. V. Wilcox. Montana Sta. Bul. 15. 1897.
(27) Forage conditions of central Montana. F. A. Spragg. Montana Sta. Bul. 36. 1902.
(28) The loco and some other poisonous plants in Montana. J. W. Blankinship. Montana Sta. Bul. 45. 1903.
(29) Contagious abortion in Montana. H. C. Gardiner. Montana Sta. Bul. 49. 1903.
(30) Native economic plants of Montana. J. W. Blankinship. Montana Sta. Bul. 56. 1905.
(31) The intradermal test in bovine tuberculosis. H. Welch. Montana Sta. Bul. 105. 1915.
(32) Hairlessness and goiter in new-born domestic animals. H. Welch. Montana Sta. Bul. 119. 1917.
(33) Poisonous plants and stock poisoning on the ranges of Montana. D. B. Swingle and H. Welch. Montana Sta. Circ. 51. 1916.
(34) Montana Sta. Rpt. 1917, p. 232.
(35) Montana Sta. Rpt. 1922, p. 26.

(36) Nebraska Sta. Rpt. 1920, p. 35.
(37) A preliminary report on the summer ranges of western Nevada sheep. P. B. Kennedy and S. B. Doten. Nevada Sta. Bul. 51. 1901.
(38) Summer ranges of eastern Nevada sheep. P. B. Kennedy. Nevada Sta. Bul. 55. 1903.
(39) Equine anemia: An account of a recent inquiry into the nature and cause of an obscure and fatal disease among horses in eastern Nevada. W. B. Mack. Nevada Sta. Bul. 68. 1909.
(40) Water hemlock (Cicuta). C. A. Jacobson. Nevada Sta. Bul. 81. 1915.
(41) One-night camps vs. established bed-grounds on Nevada sheep ranges. C. E. Fleming. Nevada Sta. Bul. 94. 1918.
(42) Range plants poisonous to sheep and cattle in Nevada. C. E. Fleming. Nevada Sta. Bul. 95. 1918. English and Spanish editions.
(43) Don't feed fox-tail hay to lambing ewes. C. E. Fleming and N. F. Peterson. Nevada Sta. Bul. 97. 1919.
(44) Arrow-grass, a new stock-poisoning plant (*Triglochin maritima*). C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 98. 1920.
(45) The narrow-leaved milkweed (*Asclepias mexicana*) and the broad-leaved or showy milkweed (*Asclepias speciosa*), plants poisonous to livestock in Nevada. C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 99. 1920.
(46) The poison parsnip or water hemlock (*Cicuta occidentalis*), a plant deadly to livestock in Nevada. C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 100. 1920.
(47) Death camas (*Zygadenus paniculatus* and *Zygadenus venenosus*), plants poisonous to sheep and cattle. C. E. Fleming, N. F. Peterson, et al. Nevada Sta. Bul. 101. 1921.
(48) Horse-flies and cattle. S. B. Doten. Nevada Sta. Bul. 102. 1921.
(49) One-night camps vs. established bed-grounds on Nevada sheep ranges. C. E. Fleming. Nevada Sta. Bul 103. 1922.
(50) Nevada Sta. Rpt. 1917, p. 75.
(51) Nevada Sta. Rpt. 1918, p. 48.
(52) Nevada Sta. Rpt. 1919, p. 39.
(53) Nevada Sta. Rpt. 1920, p. 12.
(54) Nevada Sta. Rpt. 1921, p. 11.
(55) Nevada Sta. Rpt. 1922, p. 17.
(56) Nevada Sta. Rpt. 1922, p. 19.
(57) Nevada Sta. Rpt. 1922, p. 20.
(58) Ictero-hemoglobinuria in cattle. E. Records and L. R. Vawter. Jour. Amer. Vet. Med. Assoc., 60 (1921), p. 155.
(59) Prickly pear and other cacti as food for stock, II. D. Griffiths and R. F. Hare. New Mexico Sta. Bul. 60. 1906.
(60) The range problem in New Mexico. E. O. Wooton. New Mexico Sta. Bul. 66. 1908.
(61) Experiments on the digestibility of prickly pear for cattle. R. F. Hare. New Mexico Sta. Bul. 69. 1908.
(62) The grasses and grass-like plants of New Mexico. E. O. Wooton and P. C. Standley. New Mexico Sta. Bul. 81. 1912.
(63) Range cow maintenance on yucca and sotol. L. Foster and C. W. Humble. New Mexico Sta. Bul. 114. 1918.
(64) Chamiza as an emergency feed for range cattle. L. Foster, J. L. Lantow, and C. P. Wilson. New Mexico Sta. Bul. 125. 1921.
(65) The utilization of feed by range steers of different ages. J. D. Hungerford and L. Foster. New Mexico Sta. Bul. 128. 1921.
(66) The feeding of dry-farm crops to range steers in eastern New Mexico. J. L. Lantow and H. J. Clemmer. New Mexico Sta. Bul. 131. 1922.
(67) The utility of yucca and chamiza as range supplements. L. S. Brown. New Mexico Sta. Bul. 133. 1922.
(68) New Mexico Sta. Rpt. 1918, p. 62.
(69) New Mexico Sta. Rpt. 1921, p. 41.
(70) New Mexico Sta. Rpt. 1921, p. 43.
(71) New Mexico Sta. Rpt. 1922. p. 49.
(72) Swamp fever in horses. L. Van Es, E. D. Harris, and A. F. Schalk. North Dakota Sta. Bul. 94. 1911.
(73) North Dakota Sta. Bul. 146 (Report of Director, 1920), p. 5.
(74) North Dakota Sta. Bul. 146 (Report of Director, 1920), p. 20.
(75) North Dakota Sta. Bul. 146 (Report of Director, 1920), p. 45.

(76) The trail of the short grass steer. J. H. Shepperd. North Dakota Sta. Bul. 154. 1921.
(77) North Dakota Sta. Bul. 159 (Report of Director, 1921), p. 11.
(78) North Dakota Sta. Bul. 159 (Report of Director, 1921), p. 24.
(79) History of a "swamp fever" virus carrier. A. F. Schalk and L. M. Roderick. North Dakota Sta. Bul. 168. 1923.
(80) Carrying capacity of native range grasses in North Dakota. J. H. Shepperd. Jour. Amer. Soc. Agron., 11 (1919), p. 129.
(81) Stomach worms in sheep. J. E. Guberlet. Oklahoma Sta. Bul. 137. 1921.
(82) Fattening lambs—Shelter versus open lot. R. Withycombe and E. L. Potter. Oregon Sta. Bul. 175. 1920.
(83) Growing steers. E. L. Potter and R. Withycombe. Oregon Sta. Bul. 182. 1921.
(84) The principal stock-poisoning plants of Oregon. W. E. Lawrence. Oregon Sta. Bul. 187. 1922.
(85) Infectious abortion of cattle. B. T. Simms and F. W. Miller. Oregon Sta. Bul. 192. 1922.
(86) Oregon Sta. Rpt. 1921–22, p. 40.
(87) Infectious anemia of the horse. M. Francis and R. P. Marsteller. Texas Sta. Bul. 119. 1908.
(88) The utilization of yucca for the maintenance of cattle. J. M. Jones and A. B. Conner. Texas Sta. Bul. 240. 1918.
(89) Feeding values of certain feeding stuffs. G. S. Fraps. Texas Sta. Bul. 245. 1919.
(90) An economic study of a typical ranching area on the Edwards Plateau of Texas. B. Youngblood and A. B. Cox. Texas Sta. Bul. 297. 1922.
(91) Texas Sta. Rpt. 1921, p. 4.
(92) Some recent experiments on infectious anemia of the horse. M. Francis and R. P. Marsteller. Amer. Vet. Rev., 39 (1911), p. 132.
(93) A report on the range conditions of central Washington. J. S. Cotton. Washington Col. Sta. Bul. 60. 1904.
(94) A preliminary report on the investigations of bovine red water (cystic hematuria) in Washington. J. W. Kalkus. Washington Col. Sta. Bul. 112. 1913.
(95) Plants used for food by sheep on the Mica Mountain summer range. R. K. Beattie. Washington Col. Sta. Bul. 113. 1913.
(96) A study of grazing conditions in the Wenaha National Forest. H. T. Darlington. Washington Col. Sta. Bul. 122. 1915.
(97) A study of goitre and associated conditions in domestic animals. J. W. Kalkus. Washington Col. Sta. Bul. 156. 1920.
(98) Red water or bloody urine in cattle. J. W. Kalkus. Western Washington Mo. Bul., vol. 5, No. 9, pp. 127–129. 1917.
(99) Hairless pigs: The cause and remedy. E. B. Hart and H. Steenbock. Wisconsin Sta. Bul. 297. 1918.
(100) Wyoming forage plants and their chemical composition—Studies No. 1. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 65. 1905.
(101) Digestion experiments with wethers.—Alfalfa and native hay. H. G. Knight, F. E. Hepner, and G. E. Morton. Wyoming Sta. Bul. 69. 1906.
(102) Wyoming forage plants and their chemical composition—Studies No. 2. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 70. 1906.
(103) Wyoming forage plants and their chemical composition—Studies No. 3. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 76. 1908.
(104) Digestion experiments, II.—Native hays, oat straw, pea hay, sweet clover, and alfalfa. H. G. Knight, F. E. Hepner, and T. F. McConnell. Wyoming Sta. Bul. 78. 1908.
(105) Wyoming forage plants and their chemical composition—Studies No. 4. H. G. Knight, F. E. Hepner, and A. Nelson. Wyoming Sta. Bul. 87. 1911.
(106) The chemical examination of death camas. F. W. Heyl, S. K. Loy, H. G. Knight, and O. L. Prien. Wyoming Sta. Bul. 94. 1912.
(107) The identification of the woody aster. Wyoming Sta. Bul. 97. 1913.

(108) Zygadenine: The crystallin alkaloid of *Zygadenus intermedius*. S. K. Loy, F. W. Heyl, and F. E. Hepner. Wyoming Sta. Bul. 101. 1913.
(109) The morphology of the sheep tapeworm (*Thysanosoma actinioides*). L. D. Swingle. Wyoming Sta. Bul. 102. 1914.
(110) Cattle feeding. A. D. Faville. Wyoming Sta. Bull. 108. 1915.
(111) The poisonous properties of the two-grooved milk vetch (*Astragalus bisulcatus*). O. A. Beath and E. H. Lehnert. Wyoming Sta. Bul. 112. 1917.
(112) Cattle feeding. A. D. Faville. Wyoming Sta. Bull. 117. 1917.
(113) The chemical examination of three species of larkspurs. O. A. Beath. Wyoming Sta. Bul. 120. 1919.
(114) Chemical and pharmacological examination of the woody aster. O. A. Beath. Wyoming Sta. Bul. 123. 1920.
(115) *Sarcocystis tenella:* The muscle parasite of the sheep. J. W. Scott and E. C. O'Roke. Wyoming Sta. Bul. 124. 1920.
(116) The chemical examination of the silvery lupine. O. A. Beath. Wyoming Sta. Bul. 125. 1920.
(117) Poisonous plants of Wyoming. O. A. Beath. Wyoming Sta. Bul. 126. 1921.
(118) Studies in the variation and correlation of fleeces from range sheep. J. A. Hill. Wyoming Sta. Bul. 127. 1921.
(119) Home-grown feeds for range steers. F. A. Hays. Wyoming Sta. Bul. 128. 1921.
(120) Effects of alkali and weathering upon the wool of range sheep. J. A. Hill. Wyoming Sta. Bul. 131. 1922.
(121) Insect transmission of swamp fever or infectious anemia of horses. J. W. Scott. Wyoming Sta. Bul. 133. 1922.
(122) Avian type of tuberculosis in cattle: Injection and testing. C. Elder and A. M. Lee. Wyoming Sta. Bul. 136. 1923
(123) Feeding yearling steers. F. A. Hays. Wyoming Sta. Circ. 17. 1922.
(124) Abortion disease in Wyoming. C. Elder. Wyoming. Sta. Circ. 18. 1922.
(125) Wyoming Sta. Rpt. 1920, p. 138.
(126) Wyoming Sta. Rpt. 1921, p. 134.
(127) Wyoming Sta. Rpt. 1922, p. 159.
(128) Wyoming Sta. Rpt. 1922, p. 163.
(129) Wyoming Sta. Rpt. 1922, p. 164.
(130) Some additional results obtained in the study of infectious anemia of horses. J. W. Scott. Anat. Rec., 23 (1922), p. 119.

INSULAR EXPERIMENT STATIONS

In addition to the stations conducted in continental United States, similar stations were maintained in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands, as they have been for several years. The appropriations for these stations are made directly to the United States Department of Agriculture, and their supervision is assigned to the Office of Experiment Stations, under the immediate charge of W. H. Evans. Separate reports were published as heretofore upon the work and progress of each of the stations.

The projects of all of the stations were reviewed and materially modified during the year, some being temporarily suspended and efforts concentrated on those that appeared to be most important. There were a number of changes in personnel at the stations, and these also caused some modification of lines of work.

The stations felt acutely the need of additional funds to man and finance properly the work in progress, as well as to undertake new work on certain fundamental problems which await investigation at each station.

STATISTICS OF THE STATIONS

By J. I. Schulte.

For the fiscal year ended June 30, 1922, the total income of the experiment stations was $8,125,404.37, comprising $1,440,000 Federal funds derived under the Hatch and Adams Acts, $4,901,139.50 State support, $183,193.99 income from fees, $907,934.66 returns from the sale of products, $330,078.97 income from miscellaneous sources (including $210,000 Federal appropriations for the insular stations), and $363,057.25 carried over as balances from the previous year.

The value of additions to the equipment of the stations during the year was reported as follows:

Buildings	$735, 823. 16
Library	27, 362. 20
Apparatus	92, 123. 16
Farm implements	115, 266. 80
Livestock	110, 665. 32
Miscellaneous	104, 024. 48
Total	1, 185, 265. 12

In the work of administration and inquiry the stations employed 2,166 persons, of whom 1,100 were also members of the teaching staff of the colleges and 364 assisted in the various lines of extension work. During the year the stations report having issued 1,064 publications (not all of which were received by this office during the fiscal year). The list includes annual reports, bulletins, and circulars, aggregating 24,592 pages, and these were distributed to 889,394 addresses on the regular mailing list.

The statistics of the stations by States are given in detail in the tables following:

TABLE 2.—*General statistics, 1922*

Station	Location	Director	Date of original organization	Date of organization under Hatch Act	Number on staff	Number of teachers on staff	Number of persons on staff who assist in extension work	Publications during fiscal year 1921–22: Number	Publications during fiscal year 1921–22: Pages	Number of names on mailing list
Alabama (College)	Auburn	D. T. Gray	Feb. —, 1883	Feb. 24, 1888	23	10	4	4	28	7,000
Alabama (Canebrake)	Uniontown	W. A. Cammack	Jan. 1, 1886	Apr. 1, 1888						
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		5	4				
Alaska	Sitka	C. C. Georgeson			6			1	75	
Arizona	Tucson	J. J. Thornber		—, 1889	24	16	5	9	90	9,250
Arkansas	Fayetteville	Bradford Knapp		—, 1887	28	26		7	242	12,941
California	Berkeley	C. M. Haring	—, 1875	Mar. —, 1888	123	94	80	55	1,630	40,697
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	41	23	4	10	387	2,550
Connecticut (State)	New Haven	E. H. Jenkins	Oct. 1, 1875	May 18, 1887	24	1		3	460	9,912
Connecticut (Storrs)	Storrs	do		do	12	6		3	114	6,200
Delaware	Newark	C. A. McCue		Feb. 21, 1888	14	9	3	4	122	8,500
Florida	Gainesville	Wilmon Newell		—, 1888	16	1	2	24	168	18,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	7		7	45	111	6,500
Guam	Guam	C. W. Edwards			4			4	198	
Hawaii	Honolulu	J. M. Westgate			5		2	2	95	
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	34	21	10	21	278	11,785
Illinois	Urbana	Eugene Davenport		Mar. 21, 1888	106	70	30	29	771	42,000
Indiana	Lafayette	G. I. Christie	—, 1885	Jan. —, 1888	67	21		21	516	38,478
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	80	30		29	682	30,500
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	87	39		10	334	11,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	55	24	18	14	661	9,000
Louisiana (Sugar)	New Orleans	W. R. Dodson	Sept. —, 1885							
Louisiana (State)	Baton Rouge	do	Apr. —, 1886		28	2	10	4	89	8,000
Louisiana (North)	Calhoun	do	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	14			16	953	19,342
Maryland	College Park	H. J. Patterson	—, 1888	Apr. —, 1888	29	10		8	250	22,000
Massachusetts	Amherst [1]	S. B. Haskell	—, 1882	Mar. 2, 1888	46	14	1	26	427	18,867
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	77	61	5	23	1,258	45,000
Minnesota	University Farm, St. Paul	W. C. Coffey	Mar. 7, 1885	—, 1888	98	78	2	9	598	12,000
Mississippi	Agricultural College	J. E. Ricks		Jan. 27, 1888	41	17	2	16	204	15,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	61	44		78	1,222	6,368
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		4					
Montana	Bozeman	F. B. Linfield		July 1, 1893	38	17	7	16	468	10,775
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	40	17		8	333	7,925
Nevada	Reno	S. B. Doten		Dec. —, 1887	8	1		2	33	6,000
New Hampshire	Durham	J. C. Kendall	—, 1886	Aug. 4, 1887	22	17		13	245	9,000
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		50	35	14	129	2,243	15,000
New Jersey (College)	do	do		Apr. 26, 1888	25					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	18	13	5	39	439	10,000
New York (State)	Geneva	R. W. Thatcher	Mar. —, 1882		45			21	502	24,338
New York (Cornell)	Ithaca	A. R. Mann	—, 1879	Apr. —, 1888	62	54	7	30	2,097	2,896
North Carolina (College)	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	49	3	2	3	149	7,562
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	37	9	2	15	304	9,100
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	57	3	1	92	1,813	72,367
Oklahoma	Stillwater	C. T. Dowell		Dec. 25, 1890	23	16		7	32	16,500
Oregon	Corvallis	J. T. Jardine		July —, 1888	57	30		13	333	1,448
Pennsylvania	State College	R. L. Watts		June 30, 1887	62	62	62	6	152	42,500
Pennsylvania (Nutrition)	do	H. P. Armsby [2]	—, 1907		7					
Porto Rico	Mayaguez	D. W. May			9		1	2	51	3,485
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	12	3		7	216	2,800
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	29	10	7	6	240	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	21	19		7	200	22,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	24	1		3	59	12,000
Texas	College Station	B. Youngblood		Apr. 3, 1889	48	1		21	648	61,789
Utah	Logan	William Peterson		—, 1890	37	26	18	12	218	11,000
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	13	8	2	5	644	8,000
Virginia	Blacksburg	A. W. Drinkard, jr	—, 1888	—, 1891	30	11		8	164	12,000
Virgin Islands	St. Croix	J. B. Thompson			2			2	23	521
Washington	Pullman	E. C. Johnson		—, 1891	43	13		4	164	13,625
West Virginia	Morgantown	H. G. Knight		June 11, 1888	35	22	2	1	24	28,000
Wisconsin	Madison	H. L. Russell	—, 1883	—, 1887	88	76	48	16	684	56,873
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	16	12	1	7	151	6,000
Total					2,166	1,100	364	1,064	24,592	889,394

[1] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch station at the same place.
[2] Died Oct. 19, 1921.

TABLE 3.—*Revenue and additions to equipment, 1922*

Station	Federal		State	Balances from previous year [1]	Fees	Sales	Miscel-laneous	Total	Additions to equipment						
	Hatch fund	Adams fund							Buildings	Library	Appa-ratus	Farm im-plements	Livestock	Miscel-laneous	Total
Alabama	$15,000.00	$15,000.00	$34,500.00	$6,352.92		$4,897.66		$75,750.58	$7,600.00	$500.00	$7,100.00	$1,000.00	$1,625.00	$500.00	$18,325.00
Alaska							[2]$75,000.00	75,000.00							
Arizona	15,000.00	15,000.00	66,531.60			12,110.99		108,642.59	5,383.38	1.00	2,413.14	1,633.24	1,794.14	221.02	11,445.92
Arkansas	15,000.00	15,000.00	56,945.74			2,554.22		89,499.96		99.10	1,297.53	2,171.12	962.00		4,529.75
California [3]	15,000.00	15,000.00	380,000.00					410,000.00	76,589.47	2,370.86	3,931.90	8,284.97	2,983.75	3,424.09	97,585.04
Colorado	15,000.00	15,000.00	109,686.22	9,478.31				149,164.53	7,507.65	575.00	3,676.00	586.00	4,525.00	19,464.89	36,334.54
Connecticut (State)	7,500.00	7,500.00	61,121.50	40.22	$8,681.78		11,503.61	96,347.11	349.09	778.95	178.44	415.50	55.00	518.83	2,295.81
Connecticut (Storrs)	7,500.00	7,500.00	17,500.00	2,691.78			17,796.92	52,988.70					2,000.00	250.00	2,250.00
Delaware	15,000.00	15,000.00	15,000.00			6,985.22	500.00	52,485.22	279.69	495.94		1,265.00			2,040.63
Florida	15,000.00	15,000.00	55,000.00	3,739.32		6,503.00		95,242.32	12,032.81	729.68	568.48	1,038.69	1,161.90	192.14	15,723.70
Georgia	15,000.00	15,000.00	11,765.64	3,344.69		7,558.49		52,668.82	1,500.00	1,205.76	1,000.00	3,981.64	434.85		8,122.25
Guam							[2]15,000.00	15,000.00							
Hawaii							[4]50,000.00	50,000.00							
Idaho	15,000.00	15,000.00	10,032.51			2,765.18	988.33	43,786.02	400.00	200.00	2,100.00	1,000.00	1,000.00	400.00	5,100.00
Illinois	15,000.00	15,000.00	310,293.85	37,884.08		57,174.92		435,352.85	174,011.00					23,515.32	197,526.32
Indiana	15,000.00	15,000.00	215,982.87	42,635.45	29,530.01	110,058.95	11,986.91	440,194.19	12,542.63	1,019.82	509.15	6,126.61	10,714.48	1,998.79	32,911.48
Iowa	15,000.00	15,000.00	250,000.00	30,073.25		32,559.59	246.66	342,879.50			4,886.40	577.25	5,642.20	514.47	11,620.32
Kansas	15,000.00	15,000.00	97,000.00	7,835.14		34,084.87		168,920.01	279,733.00	75.70	80.00	5,984.04	1,200.79	396.51	287,470.04
Kentucky	15,000.00	15,000.00	50,000.00	15,050.38	42,177.91	33,107.26	5,700.00	176,035.55		516.54	637.32	1,101.50	690.00	190.18	3,135.54
Louisiana	15,000.00	15,000.00	50,000.04	31,209.92				111,209.96	7,127.00	379.02	2,340.69	3,249.17	1,216.30	2,180.85	16,493.03
Maine	15,000.00	15,000.00	31,146.23		12,028.48		352.12	73,526.83		483.65	501.60	424.50	26.26	125.31	1,561.35
Maryland	15,000.00	15,000.00	49,623.67			11,018.27		90,641.94		346.71	895.20	1,238.04	500.00	177.95	3,157.90
Massachusetts	15,000.00	15,000.00	99,152.86		18,648.95	9,690.25	378.20	157,870.26	1,010.12	635.39	292.09	1,167.54	230.82		3,335.96
Michigan	15,000.00	15,000.00	90,000.00		40.00	6,453.84	4,588.62	131,082.46	5,875.48	671.92	1,266.52	3,062.15	1,841.60		12,717.67
Minnesota	15,000.00	15,000.00	306,942.51			121,366.10	2,504.09	460,812.70	21,184.34	1,794.76	3,461.30	8,790.44	9,844.53		45,075.37
Mississippi	15,000.00	15,000.00	102,377.14	5,545.72	149.00	15,090.45	405.84	153,568.15	183.36	259.03	2,212.37	1,121.25	6,770.00	1,147.01	11,693.02
Missouri	15,000.00	15,000.00	42,086.66	2,045.21	23,043.59	14,535.11		111,710.57	318.95	606.49	1,194.75	571.93	3,540.82		6,232.94
Montana	15,000.00	15,000.00	134,468.57			8,582.64		173,051.21	15,312.00	500.00	482.00	5,180.00	600.00	1,618.00	23,692.00
Nebraska	15,000.00	15,000.00	71,741.83	13,358.13		71,703.27		186,803.23		459.39	3,521.15	4,574.87	9,658.56	12,947.72	31,161.69
Nevada	15,000.00	15,000.00	1,878.15	329.45		1,811.55		34,019.15	1,861.34	166.74	387.42	79.75	1,472.80	38.00	4,006.05
New Hampshire	15,000.00	15,000.00	5,000.00	1,215.92		2,910.97	13,064.35	52,191.24		450.00	1,253.69	83.75	325.00	667.03	2,809.47
New Jersey (College)	15,000.00	15,000.00						30,000.00	728.50	1,355.47	2,661.63	49.91	666.70	2,239.36	7,701.57
New Jersey (State)			142,956.51		47,550.02	27,093.49	2,173.37	219,773.39							
New Mexico	15,000.00	15,000.00	7,500.00	18,150.16		9,084.54		64,734.70	1,596.40	118.96	476.07	863.73	1,893.59	126.56	5,075.31
New York (Cornell)	13,500.00	13,500.00	183,474.32			34,449.97	5,011.81	249,936.10	10,087.02	1,074.62	4,002.35	3,633.21	433.96	1,615.95	20,847.11

New York (State)[4]	1,500.00	1,500.00	198,354.63	2,836.47				204,191.10		1,890.00	4,200.00	2,600.00		1,800.00	10,490.00
North Carolina	15,000.00	15,000.00	162,737.00	920.49		3,237.39	4,180.48	201,075.36	5,771.01		179.42	2,170.12	1,250.00	532.10	9,902.65
North Dakota	15,000.00	15,000.00	151,334.43	7,699.27			20,082.97	209,116.67	6,500.00	64.01	1,234.67	7,044.42	7,140.81		21,983.94
Ohio	15,000.00	15,000.00	310,640.85	43,282.80		40,304.10		421,227.75		943.91	3,647.79	3,647.79	1,015.00	3,000.00	12,254.49
Oklahoma	15,000.00	15,000.00	10,500.00	2,525.68		5,094.84		48,120.52		553.59	1,398.53	526.61	863.70		3,342.43
Oregon	15,000.00	15,000.00	107,543.78	36,023.59		36,860.50	4,000.00	214,427.87	3,500.00	25.00	3,110.72	4,015.79	4,457.00	2,090.82	17,199.33
Pennsylvania	15,000.00	15,000.00	36,435.63		1,344.25	12,755.27	6,780.31	87,315.46		669.63	3,804.65	169.17	3,959.13	181.18	8,783.76
Porto Rico							[2] 50,000.00	50,000.00	2,258.09	183.02	303.69	296.49			3,041.29
Rhode Island	15,000.00	15,000.00	9,051.80	447.31		5,495.72		44,994.83	463.00	460.00	225.00	177.00	50.00	676.00	2,052.00
South Carolina	15,000.00	15,000.00	57,987.02			4,182.29		92,169.31	1,200.00	150.00	400.00	1,000.00	1,000.00	400.00	4,150.00
South Dakota	15,000.00	15,000.00	14,420.00	7,633.98		2,018.30	5,896.59	59,968.87		125.00	595.23	600.00	225.00		1,545.28
Tennessee	15,000.00	15,000.00	33,294.89			233.21		63,528.10	4,000.00	459.34	239.35	3,188.66	2,500.00	399.21	10,836.59
Texas	15,000.00	15,000.00	201,535.00	3,028.30		54,393.27		288,956.57	13,540.33	601.89	10,275.44	7,904.08	1,100.00	11,103.04	44,521.78
Utah	15,000.00	15,000.00	50,123.77	9,513.89		10,527.07		100,164.23	2,500.00	300.00	700.00		500.00	400.00	4,400.00
Vermont	15,000.00	15,000.00				177.60		30,177.60	184.18	58.38	1,145.89	98.83	152.50		1,639.78
Virginia	15,000.00	15,000.00	45,297.50	12,288.39		8,325.15	550.10	9[illegible],461.14	1,807.26	557.03	182.97	951.75		222.01	3,721.02
Virgin Islands							[2] 20,000.00	20,000.00	5,667.45	8.10	12.98	144.94			5,833.47
Washington	15,000.00	15,000.00	164,674.78	1,499.92		49,598.59		185,773.29	3,218.61	522.31	1,106.02	3,118.60	2,231.00	493.69	10,743.23
West Virginia	15,000.00	15,000.00	120,000.00			27,313.83	1,387.69	178,701.52	30,000.00	600.00	1,520.00	1,753.73	2,525.00	829.21	37,227.97
Wisconsin	15,000.00	15,000.00	215,000.00					245,000.00	12,000.00	1,320.46	3,154.71	4,322.04	3,296.60	2,224.89	26,318.70
Wyoming	15,000.00	15,000.00	12,500.00	4,377.61		3,266.73		50,144.34			1,277.86	2,230.98	4,536.50	5,202.29	13,297.63
Total	720,000.00	720,000.00	4,901,139.50	[illegible]63,057.25	183,193.99	907,934.66	330,078.9[illegible]	8,125,404.3[illegible]	735,823.1[illegible]	27,312.20	92,123.1[illegible]	115,266.80	110,665.32	101,024.48	1,185,255.12

[1] Not including balances from Federal funds.
[2] Supported by direct appropriation to the United States Department of Agriculture.
[3] The resources from other than Federal funds are estimated.
[4] Including balances from previous year: $7.84 Hatch and $0.24 Adams.

TABLE 4.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$8,912.48	$1,759.00	$127.91	$341.08	$186.76	--------	$388.43
Arizona	15,000.00	8,574.87	392.58	73.20	915.24	74.88	--------	469.30
Arkansas	15,000.00	8,093.56	2,001.04	568.43	235.51	186.39	$93.42	192.96
California	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Colorado	15,000.00	11,711.91	1,704.56	497.00	33.87	57.92	--------	30.19
Connecticut (State)	7,500.00	7,500.00	--------	--------	--------	--------	--------	--------
Connecticut (Storrs)	7,500.00	7,500.00	--------	--------	--------	--------	--------	--------
Delaware	15,000.00	9,656.33	851.41	1,803.89	762.61	63.88	239.36	309.68
Florida	15,000.00	11,769.14	382.01	--------	5.18	26.85	17.02	145.31
Georgia	15,000.00	8,495.96	1,784.57	725.59	708.41	189.93	610.33	54.00
Idaho	15,000.00	10,697.14	2,504.31	373.38	13.31	28.74	91.25	107.36
Illinois	15,000.00	13,929.06	770.50	271.18	29.26	--------	--------	--------
Indiana	15,000.00	14,162.50	715.81	--------	20.50	--------	--------	19.05
Iowa	15,000.00	8,415.00	290.35	1,111.60	357.90	40.42	143.29	93.00
Kansas	15,000.00	9,883.33	4,703.02	9.68	104.62	--------	--------	2.60
Kentucky	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Louisiana	15,000.00	9,056.81	2,964.18	325.52	164.44	56.83	435.69	--------
Maine	15,000.00	6,503.78	2,331.08	241.48	437.49	234.04	706.63	34.75
Maryland	15,000.00	13,183.12	853.18	578.88	8.14	--------	196.31	12.77
Massachusetts	15,000.00	14,632.50	367.50	--------	--------	--------	--------	--------
Michigan	15,000.00	12,947.75	2,052.25	--------	--------	--------	--------	--------
Minnesota	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Mississippi	15,000.00	9,600.04	3,022.73	--------	215.80	104.35	458.48	--------
Missouri	15,000.00	11,260.82	1,542.85	--------	80.80	185.88	40.44	182.64
Montana	15,000.00	14,385.00	--------	156.35	416.05	.86	--------	2.25
Nebraska	15,000.00	14,580.00	420.00	--------	--------	--------	--------	--------
Nevada	15,000.00	9,471.65	2,816.82	105.91	277.53	37.58	98.42	--------
New Hampshire	15,000.00	9,916.00	1,022.40	804.84	647.68	303.79	600.00	149.68
New Jersey	15,000.00	10,004.02	683.46	512.96	300.28	46.95	637.50	192.10
New Mexico	15,000.00	5,145.28	3,523.84	1,713.94	172.74	218.75	146.50	5.64
New York (State)	1,500.00	333.28	1,163.25	--------	--------	--------	--------	--------
New York (Cornell)	13,500.00	9,520.00	1,832.90	--------	16.34	27.20	71.37	188.86
North Carolina	15,000.00	9,096.33	4,012.65	--------	240.72	223.48	--------	--------
North Dakota	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Ohio	15,000.00	13,548.32	1,451.68	--------	--------	--------	--------	--------
Oklahoma	15,000.00	6,940.75	2,434.12	500.85	255.27	28.33	50.23	471.73
Oregon	15,000.00	9,715.67	3,038.28	683.16	33.39	26.39	28.10	308.15
Pennsylvania	15,000.00	11,800.00	749.10	1,609.67	1.25	62.82	4.50	39.50
Rhode Island	15,000.00	6,912.95	4,342.02	1,857.81	172.35	270.61	114.21	16.10
South Carolina	15,000.00	7,919.42	2,636.74	122.67	408.17	139.58	132.84	178.97
South Dakota	15,000.00	8,364.93	2,085.11	3,285.58	77.08	15.86	--------	75.24
Tennessee	15,000.00	11,017.62	451.40	651.64	268.69	38.78	941.04	25.29
Texas	15,000.00	13,329.99	32.50	--------	309.61	--------	14.90	--------
Utah	15,000.00	11,096.28	2,276.01	--------	32.48	36.63	--------	778.49
Vermont	15,000.00	6,025.83	1,295.48	4,352.35	226.57	69.40	841.00	22.53
Virginia	15,000.00	9,714.92	3,013.10	263.64	325.80	145.28	57.82	21.22
Washington	15,000.00	8,536.51	2,371.78	2,139.91	44.11	--------	71.82	53.04
West Virginia	15,000.00	12,537.49	704.25	--------	--------	56.55	--------	--------
Wisconsin	15,000.00	9,075.77	2,494.80	--------	22.61	2.85	19.50	580.04
Wyoming	15,000.00	10,833.51	24.22	485.73	--------	--------	252.96	386.19
Total	720,000.00	516,307.62	75,868.84	25,954.75	8,682.88	3,188.56	7,114.93	5,537.06

he act of March 2, 1887 (Hatch Act), for the year ended June 30, 1922

Classified expenditures											
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
$270.72	$384.65	$373.32	$452.77	$392.64	$534.52	----	$140.80	$97.18	----	$637.74	----
260.36	----	790.56	1.00	350.57	504.20	$1,454.33	228.50	606.19	----	304.22	----
1,131.89	246.01	624.81	----	398.71	19.25	424.16	30.00	415.56	----	338.30	----
96.46	----	276.95	36.67	38.15	134.05	14.47	120.00	211.61	----	36.19	----
----	----	----	----	----	----	----	----	----	----	----	----
124.61	21.73	----	128.84	266.52	173.06	29.14	----	528.63	$31.06	9.25	----
210.84	220.88	468.00	626.96	170.87	21.75	113.98	----	490.96	4.65	325.60	----
815.99	561.51	126.41	142.27	422.61	54.95	18.95	17.00	271.52	----	----	----
231.56	4.10	199.50	34.24	133.50	7.10	109.95	----	385.39	----	79.17	----
23.00	----	----	----	8.25	----	----	36.00	14.89	----	----	----
916.74	----	3,474.85	----	52.10	10.82	----	----	94.93	----	----	----
205.80	----	----	----	32.10	7.98	----	----	50.87	----	----	----
224.59	10.00	403.05	93.65	122.31	232.70	----	----	562.35	75.56	272.32	----
893.08	----	2,191.55	438.45	236.62	34.34	70.92	----	279.43	----	366.36	----
102.78	----	----	27.88	.60	----	36.34	----	----	----	----	----
----	----	----	----	----	----	----	----	----	----	----	----
----	----	----	----	----	----	----	----	----	----	----	----
576.82	21.37	293.45	----	16.70	70.00	----	461.52	78.12	1.18	79.44	----
580.27	----	741.26	12.00	58.28	10.88	19.21	57.51	222.41	----	4.75	----
2.09	----	----	----	----	34.42	----	----	----	----	2.98	----
225.48	----	67.82	32.24	129.10	43.25	4.50	542.82	617.54	----	529.34	----
166.10	158.96	----	401.81	171.77	63.96	207.15	----	363.69	----	22.17	----
478.18	75.53	----	25.50	32.87	80.81	5.00	----	1,857.20	28.50	39.14	----
465.06	130.53	1,138.59	102.76	661.14	63.53	----	556.77	436.24	----	518.69	----
----	----	----	----	----	----	----	----	3.06	----	----	$0.41
323.81	10.00	----	----	461.47	158.43	581.28	----	292.80	----	15.54	----
289.99	392.30	736.07	----	----	----	----	----	----	----	8.46	----
----	----	----	----	----	----	----	----	----	----	----	----
----	----	----	----	----	----	----	----	----	----	----	----
788.60	33.64	1,485.91	181.77	370.48	43.83	356.50	786.90	192.59	----	78.50	----
151.01	28.99	----	9.50	127.34	----	72.00	----	776.58	1.44	----	----
342.99	46.11	----	----	13.98	----	----	----	330.08	----	----	----
324.65	243.02	403.96	111.85	127.96	18.80	.80	----	37.92	.90	44.09	----
536.62	603.93	932.66	723.91	353.69	170.90	----	6.00	84.71	----	49.19	----
561.32	----	141.94	----	64.99	28.85	61.25	225.00	----	----	12.85	----
203.31	2.50	----	380.81	230.18	332.14	40.32	----	233.47	----	182.81	----
14.50	----	----	5.00	652.01	365.74	----	----	----	----	275.75	----
203.81	----	113.71	10.15	8.47	3.63	94.35	----	321.72	----	24.27	----
899.29	261.36	----	45.04	75.45	78.66	219.13	----	504.93	----	82.98	----
721.26	115.28	71.04	186.50	177.59	94.97	----	----	40.00	----	51.58	----
189.30	51.69	----	----	22.14	75.85	335.25	----	1,108.60	----	----	----
477.81	128.01	----	----	371.40	----	----	----	461.19	----	263.30	----
1,134.27	194.03	12.50	----	53.29	95.22	1,190.06	----	125.06	----	----	----
93.38	----	2,106.50	----	190.10	9.75	250.13	----	----	----	367.53	----
15,257.34	3,946.13	17,174.41	4,211.57	6,995.95	3,578.34	5,709.17	3,208.82	12,097.42	143.29	5,022.51	.41

TABLE 5.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000.00	$10,219.06	$383.77	$13.41	$66.86	----	$683.70	$175.45
Arizona	15,000.00	11,824.01	553.42	106.12	58.43	----	98.27	70.43
Arkansas	15,000.00	9,521.25	1,944.93	65.58	49.71	$2.10	712.72	671.29
California	15,000.00	9,299.96	1,735.68	74.46	4.08	59.03	934.24	669.19
Colorado	15,000.00	13,019.23	196.85	9.27	17.25	----	987.70	82.81
Connecticut (State)	7,500.00	6,006.86	395.80	24.93	45.55	449.83	203.85	136.89
Connecticut (Storrs)	7,500.00	7,500.00	----	----	----	----	----	----
Delaware	15,000.00	11,715.10	501.39	6.35	48.86	----	1,361.78	195.62
Florida	15,000.00	12,576.68	256.41	24.16	106.91	98.13	330.46	276.66
Georgia	15,000.00	10,060.89	193.61	29.56	254.35	648.96	652.65	40.43
Idaho	15,000.00	10,080.87	2,235.88	8.00	187.32	122.65	698.87	604.23
Illinois	15,000.00	14,126.75	720.00	----	2.71	----	6.00	----
Indiana	15,000.00	11,671.70	358.72	26.61	1.00	----	661.02	544.80
Iowa	15,000.00	8,858.12	1,857.48	71.81	----	314.81	1,038.47	672.88
Kansas	15,000.00	10,054.16	3,086.62	44.79	9.90	3.50	249.29	237.22
Kentucky	15,000.00	14,995.80	4.20	----	----	----	----	----
Louisiana	15,000.00	10,999.94	575.00	47.70	66.52	286.49	707.51	157.35
Maine	15,000.00	13,933.87	349.00	58.35	21.15	33.76	----	16.85
Maryland	15,000.00	12,929.22	130.00	24.30	159.86	932.89	407.33	51.97
Massachusetts	15,000.00	14,947.50	52.50	----	----	----	----	----
Michigan	15,000.00	14,554.20	445.80	----	----	----	----	----
Minnesota	15,000.00	15,000.00	----	----	----	----	----	----
Mississippi	15,000.00	9,380.45	2,043.74	----	99.57	125.46	----	949.21
Missouri	15,000.00	7,242.61	1,557.79	47.18	112.80	137.35	299.61	912.70
Montana	15,000.00	11,439.88	1,707.66	1.63	66.39	----	633.01	184.25
Nebraska	15,000.00	14,978.60	----	----	----	----	----	15.90
Nevada	15,000.00	8,770.20	2,570.27	25.70	135.93	298.85	308.95	144.35
New Hampshire	15,000.00	11,460.00	1,257.31	22.58	51.60	----	589.17	222.02
New Jersey	15,000.00	12,165.00	374.03	35.25	3.72	637.50	601.80	176.82
New Mexico	15,000.00	8,535.68	2,986.64	88.35	341.42	339.87	791.84	385.43
New York (State)	1,500.00	1,500.00	----	----	----	----	----	----
New York (Cornell)	13,500.00	10,277.77	2,710.00	16.00	----	----	473.64	17.59
North Carolina	15,000.00	15,000.00	----	----	----	----	----	----
North Dakota	15,000.00	15,000.00	----	----	----	----	----	----
Ohio	15,000.00	11,910.72	2,841.45	----	----	----	204.24	13.42
Oklahoma	15,000.00	13,140.00	1,074.62	.59	----	2.20	142.35	168.15
Oregon	15,000.00	13,372.50	256.67	----	40.21	33.34	601.78	363.21
Pennsylvania	15,000.00	10,884.74	192.47	43.51	53.29	12.38	1,174.35	42.23
Rhode Island	15,000.00	9,516.02	3,093.21	1.90	27.10	612.91	125.98	104.55
South Carolina	15,000.00	10,643.80	2,174.12	8.50	15.83	274.60	195.71	287.08
South Dakota	15,000.00	8,754.89	3,571.17	32.09	42.40	----	85.47	287.14
Tennessee	15,000.00	13,350.00	26.85	7.68	81.50	183.76	581.57	9.65
Texas	15,000.00	14,116.70	436.00	----	3.26	----	----	5.60
Utah	15,000.00	11,620.46	2,180.22	9.90	117.42	----	640.45	113.53
Vermont	15,000.00	10,080.00	2,753.24	103.16	7.27	44.58	262.64	188.92
Virginia	15,000.00	10,224.80	3,154.29	----	109.05	----	64.67	217.73
Washington	15,000.00	12,783.28	1,154.55	12.62	5.00	----	124.22	22.38
West Virginia	15,000.00	10,660.11	948.37	3.72	----	87.54	94.56	363.77
Wisconsin	15,000.00	8,210.00	3,459.05	----	----	----	172.06	364.51
Wyoming	15,000.00	11,310.66	430.97	----	----	----	669.30	145.09
Total	720,000.00	560,224.04	58,931.75	1,095.76	2,414.22	5,742.48	18,571.23	10,309.30

the act of March 16, 1906 (Adams Act), for the year ended June 30, 1922

Classified expenditures									
Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs
--------	$817.55	$27.32	$493.20	$34.50	$718.08	$358.75	$392.39	--------	$615.96
--------	--------	--------	454.38	87.75	958.81	--------	632.55	--------	155.83
$457.15	340.83	--------	255.58	17.15	492.16	195.00	262.16	--------	12.39
--------	75.00	51.83	41.69	63.01	1,559.47	167.75	77.76	$8.00	178.85
--------	4.70	10.00	12.05	4.25	312.59	--------	337.70	--------	5.60
--------	76.41	--------	82.82	8.87	--------	--------	68.19	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
27.73	--------	32.19	14.60	77.85	875.59	--------	124.14	--------	18.80
279.63	--------	14.00	216.88	32.20	119.09	--------	642.19	--------	26.60
--------	2,303.02	138.28	.60	13.85	21.01	540.45	102.35	--------	--------
--------	140.40	8.50	202.40	13.03	185.41	16.80	489.64	--------	6.00
--------	140.54	--------	.75	--------	--------	3.25	--------	--------	--------
9.60	--------	15.20	382.43	12.18	232.82	880.90	203.02	--------	--------
22.31	957.03	--------	499.33	14.30	335.35	--------	214.36	--------	143.75
--------	650.46	--------	102.86	17.52	--------	75.44	11.32	--------	456.92
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
5.12	61.40	172.01	--------	168.51	1,508.70	--------	179.85	--------	63.90
--------	137.22	37.91	--------	--------	308.62	--------	103.27	--------	--------
--------	--------	2.88	2.95	12.91	279.54	--------	51.01	1.20	13.94
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	16.00	234.68	367.20	300.00	1,292.07	--------	183.42	--------	8.20
--------	3,412.82	5.00	71.79	12.50	845.53	251.34	--------	--------	90.98
--------	--------	--------	6.93	33.68	250.03	--------	676.54	--------	--------
--------	--------	--------	--------	--------	--------	5.50	--------	--------	--------
--------	572.40	28.45	28.10	22.10	283.65	1,493.80	317.25	--------	--------
--------	342.46	--------	28.22	3.61	612.01	--------	66.52	--------	344.50
14.97	360.00	176.50	131.84	44.15	226.05	--------	2.37	--------	50.00
44.68	167.70	13.65	145.53	48.16	476.07	330.00	4.96	--------	300.02
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	5.00	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	5.50	--------	--------	--------	--------	8.67	16.00	--------	--------
--------	340.00	.19	62.63	--------	--------	56.80	12.47	--------	--------
--------	--------	6.05	136.44	--------	147.97	--------	41.83	--------	--------
10.00	2.95	185.84	34.65	34.72	1,916.82	169.46	76.86	--------	165.73
--------	756.34	30.77	28.93	--------	180.30	46.00	--------	--------	475.99
259.56	--------	5.00	73.40	3.11	1,026.62	6.00	--------	--------	26.67
36.65	264.10	125.00	429.87	206.38	636.73	90.00	325.92	--------	112.19
--------	--------	78.53	60.57	33 93	280.75	--------	296.31	--------	8.90
--------	--------	--------	245.47	--------	191.40	--------	--------	--------	1.57
--------	--------	--------	1.50	125.39	--------	--------	191.13	--------	--------
--------	71.60	7.34	23.38	--------	926.76	152.50	276.61	.80	101.20
120.65	746.82	--------	76.71	1.20	54.45	--------	92.08	--------	137.55
--------	--------	--------	122.41	3.67	516.57	66.00	189.30	--------	--------
2.75	508.10	--------	93.71	--------	1,674.85	--------	562.52	--------	--------
--------	2,536.60	--------	6.75	--------	193.14	48.00	9.89	--------	--------
--------	427.54	6.06	221.75	742.35	126.49	839.25	80.54	--------	--------
1,290.80	16,235.49	1,413.18	5,165.30	2,192.83	19,765.50	5,801.66	7,314.42	10.00	3,522.04

TABLE 6.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906*

State or Territory	Hatch Act		Adams Act	
	1888-1921	1922	1906-1921	1922
Alabama	$508,956.42	$15,000.00	$206,619.89	$15,000.00
Arizona	474,803.10	15,000.00	209,955.61	15,000.00
Arkansas	508,139.12	15,000.00	209,900.00	15,000.00
California	510,000.00	15,000.00	209,926.84	15,000.00
Colorado	509,718.82	15,000.00	208,638.93	15,000.00
Connecticut	510,000.00	15,000.00	210,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	508,382.87	15,000.00	205,475.12	15,000.00
Florida	509,966.06	15,000.00	209,996.06	15,000.00
Georgia	505,593.43	15,000.00	197,092.87	15,000.00
Idaho	434,324.13	15,000.00	205,842.22	15,000.00
Illinois	509,564.95	15,000.00	209,851.62	15,000.00
Indiana	509,901.19	15,000.00	210,000.00	15,000.00
Iowa	510,000.00	15,000.00	210,000.00	15,000.00
Kansas	509,995.00	15,000.00	210,000.00	15,000.00
Kentucky	509,996.57	15,000.00	210,000.00	15,000.00
Louisiana	510,000.00	15,000.00	210,000.00	15,000.00
Maine	509,999.62	15,000.00	210,000.00	15,000.00
Maryland	509,967.40	15,000.00	209,236.48	15,000.00
Massachusetts	509,617.70	15,000.00	210,000.00	15,000.00
Michigan	509,676.10	15,000.00	206,341.20	15,000.00
Minnesota	509,917.78	15,000.00	209,345.00	15,000.00
Mississippi	510,000.00	15,000.00	210,000.00	15,000.00
Missouri	505,097.24	15,000.00	209,999.90	15,000.00
Montana	420,000.00	15,000.00	207,417.04	15,000.00
Nebraska	509,932.16	15,000.00	210,000.00	15,000.00
Nevada	509,214.32	15,000.00	208,180.28	15,000.00
New Hampshire	510,000.00	15,000.00	210,000.00	15,000.00
New Jersey	509,949.97	15,000.00	209,392.06	15,000.00
New Mexico	474,509.05	15,000.00	210,000.00	15,000.00
New York	509,765.43	14,992.16	209,463.25	14,999.76
North Carolina	510,000.00	15,000.00	195,000.00	15,000.00
North Dakota	451,502.26	15,000.00	209,638.85	15,000.00
Ohio	510,000.00	15,000.00	208,514.02	15,000.00
Oklahoma	434,568.96	15,000.00	191,360.56	15,000.00
Oregon	495,156.64	15,000.00	205,000.00	15,000.00
Pennsylvania	509,967.43	15,000.00	209,995.41	15,000.00
Rhode Island	510,000.00	15,000.00	207,464.20	15,000.00
South Carolina	509,542.15	15,000.00	208,460.12	15,000.00
South Dakota	453,250.00	15,000.00	205,000.00	15,000.00
Tennessee	510,000.00	15,000.00	210,000.00	15,000.00
Texas	510,000.00	15,000.00	207,592.26	15,000.00
Utah	375,000.00	15,000.00	209,821.94	15,000.00
Vermont	510,000.00	15,000.00	210,000.00	15,000.00
Virginia	507,824.12	15,000.00	209,949.01	15,000.00
Washington	447,102.65	15,000.00	206,080.11	15,000.00
West Virginia	509,968.71	15,000.00	207,859.12	15,000.00
Wisconsin	510,000.00	15,000.00	210,000.00	15,000.00
Wyoming	495,000.00	15,000.00	210,000.00	15,000.00
Total	23,862,121.35	719,992.16	9,984,409.97	719,999.76

PUBLICATIONS

The publications of the stations are steadily increasing in volume and diversity of subject matter. The list here given of bulletins, circulars, and reports received by the Office of Experiment Stations during the year 1921-22, includes 118 publications which deal with animal husbandry subjects including dairying, 75 with field crops, 61 with horticulture, 55 with entomology and zoology, 38 with soils and fertilizers, 34 with plant diseases, 30 with agricultural economics, 18 with veterinary medicine, 13 with agricultural engineering, and lesser numbers with other subjects. In addition, there are 58 entries under annual reports and 41 under regulatory publications.

It should be noted that this list does not include press bulletins and other fugitive publications, or articles published in scientific journals. To an increasing extent station investigators are publishing the more technical results of their work in various scientific journals. Such publication has reached considerable proportions and represents a very important part of the scientific output of the stations.

LIST OF PUBLICATIONS OF THE EXPERIMENT STATIONS DURING THE FISCAL YEAR 1922

AGRICULTURAL CHEMISTRY

Adsorption at liquid-vapor and liquid-liquid interfaces and some related phenomena. H. H. King. (Kansas Sta. Tech. Bul. 9, pp. 41, figs. 7.)
Rate and extent of solubility of minerals and rocks under different treatments and conditions. G. J. Bouyoucos. (Michigan Sta. Tech. Bul. 50, pp. 32.)
A chemical study of broomcorn and broomcorn silage. C. T. Dowell and W. G. Friedemann. (Oklahoma Sta. Bul. 135, pp. 7.)
A method for determining adulterants in butterfat. G. Spitzer and W. F. Epple. (Indiana Sta. Bul. 254, pp. 16, fig. 1.)

BOTANY AND PLANT PHYSIOLOGY

Some physical and chemical studies of certain clones and sibs of brome grass L. R. Waldron. (North Dakota Sta. Research Bul. 152, pp. 28, pls. 3, figs. 3.)
Physical characters and some of their correlations in *Bromus inermis*. L. R. Waldron. (North Dakota Sta. Research Bul. 153, pp. 31, figs. 5.)
Studies in pollen, with special reference to longevity. H. E. Knowlton. (New York Cornell Sta. Mem. 52, pp. 747–793.)
The seasonal march of the climatic conditions of a greenhouse, as related to plant growth. E. S. Johnston. (Maryland Sta. Bul. 245, pp. 41–98, figs. 7.)
The effects of shading some horticultural plants. J. H. Gourley and G. T. Nightingale. (New Hampshire Sta. Tech. Bul. 18, pp. 22, figs. 19.)
Liberation of organic matter by roots of growing plants. T. L. Lyon and J. K. Wilson. (New York Cornell Sta. Mem. 40, pp. 44, figs. 9.)
A study of the influence of physical soil factors and of various fertilizer chemicals on the growth of the carnation plant. F. R. Pember and G. E. Adams. (Rhode Island Sta. Bul. 187, pp. 94.)
An investigation of sulphur as a plant food. G. A. Olsen and J. L. St. John. (Washington Sta. Tech. Bul. 165, pp. 69, figs. 11.)
Titanium, barium, strontium, and lithium in certain plants. W. P. Headden. (Colorado Sta. Bul. 267, pp. 20.)
Investigations on the hardening process in vegetable plants. J. T. Rosa, jr. (Missouri Sta. Research Bul. 48, pp. 97, figs. 16.)
Respiration of shelled corn. C. H. Bailey. (Minnesota Sta. Tech. Bul. 3, pp. 44, figs. 12.)
Common weeds and their control. J. G. Fiske. (New Jersey Stas. Circ. 125, pp. 19, figs. 14.)
Nineteen noxious weeds of Indiana.—Description, eradication, and control of the nineteen weeds designated as noxious in the Indiana seed law. A. A. Hansen. (Indiana Sta. Circ. 106, pp. 32, figs. 20.)
The blueweed and its eradication. R. E. Karper. (Texas Sta. Bul. 292, pp. 13, figs. 5.)

GENETICS

The genetic relations of plant colors in maize. R. A. Emerson. (New York Cornell Sta. Mem. 39, pp. 156, pls. 11.)
The inheritance of salmon silk color in maize. E. G. Anderson. (New York Cornell Sta. Mem. 48, pp. 539–554, pls. 4.)

BACTERIOLOGY

Studies on the physiology of some plant pathogenic bacteria. (North Carolina Sta. Tech. Bul. 20, pp. 47, fig. 1.)
The use of agar slants in detecting fermentation; Rose bengal as a general bacterial stain; A modification and new application of the Gram stain. H. J. Conn and G. J. Hucker. (New York State Sta. Tech. Bul. 84, pp. 9.)
The use of various culture media in characterizing actinomycetes. H. J. Conn. (New York State Sta. Tech. Bul. 83, pp. 26.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. (Massachusetts Sta. Met. Buls. 390–401, pp. 4 each.)
Ohio weather for 1920. W. H. Alexander and C. A. Patton. (Ohio Sta. Bul. 352, pp. 261–354, figs. 63.)

SOILS

Soil analysis and soil and plant interrelations. D. R. Hoagland. (California Sta. Circ. 235, pp. 7.)
Studies on the reactions between soils and various chemical compounds. C. H. Spurway. (Michigan Sta. Tech. Bul. 51, pp. 29.)
A comparison of the calcium content of some virgin and cultivated soils of Kentucky by an improved method for the estimation of this element. O. M. Shedd. (Kentucky Sta. Research Bul. 236, pp. 305–330.)
The removal of mineral plant food by natural drainage waters. J. S. McHargue and A. M. Peter. (Kentucky Sta. Research Bul. 237, pp. 333–362, fig. 1.)
Availability of potash in some soil-forming minerals. G. S. Fraps. (Texas Sta. Bul. 284, pp. 16, figs. 3.)
Fallow experiments in south central Montana.—Results from the Experimental Dry Farm, Huntley, Mont. A. E. Seemans. (Montana Sta. Bul. 142, pp. 24.)
Summer tillage in Montana. C. McKee. (Montana Sta. Circ. 102, pp. 4.)
Investigations in dry farm tillage. M. A. McCall and H. F. Holtz. (Washington Sta. Bul. 164, pp. 51 + [5], figs. 12.)
Relation of soil nitrogen, nitrification and ammonification to pot experiments. G. S. Fraps. (Texas Sta. Bul. 283, pp. 51, figs. 3.)
Solvent action of nitrification and sulfofication. J. W. Ames. (Ohio Sta. Bul. 351, pp. 223–257.)
The chemical composition of the soils of the Belvidere area in New Jersey. A. W. Blair and H. C. McLean. (New Jersey Stas. Bul. 362, pp. 16, figs. 2.)
The chemical composition of the soils of the Millville area in New Jersey. A. W. Blair and H. C. McLean. (New Jersey Stas. Bul. 366, pp. 15, figs. 4.)
Composition of some soils from the Chautauqua County grape belt. R. C. Collison. (New York State Sta. Tech. Bul. 85, pp. 15, fig. 1.)
Peoria County soils. J. G. Mosier, S. V. Holt, E. Van Alstine, and F. W. Garrett. (Illinois Sta. Soil Rpt. 19, pp. [1] + 57, pls. 2, figs. 8.)
Bureau County soils. J. G. Mosier, S. V. Holt, E. Van Alstine, and F. W. Garrett. (Illinois Sta. Soil Rpt. 20, pp. 72, pls. 3, figs. 12.)
McHenry County soils. J. G. Mosier, R. W. Dickenson, H. W. Stewart, E. Van Alstine, and H. J. Snider. (Illinois Sta. Soil Rpt. 21, pp. 50, pls. 2, figs. 10.)
Iroquois County soils. J. G. Mosier, S. V. Holt, E. Van Alstine, and H. J. Snider. (Illinois Sta. Soil Rpt. 22, pp. 60, pls. 4, figs. 7.)
Soil survey of Iowa—Wayne County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 19, pp. 56, pl. 1, figs. 15.)
Soil survey of Iowa—Hamilton County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 20, pp. 54, pl. 1, figs. 11.)
Soil survey of Iowa—Louisa County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 21, pp. 70, pl. 1, figs. 12.)
The silt loam soils of eastern Washington and their management. F. J. Sievers and H. F. Holtz. (Washington Sta. Bul. 166, pp. 62, figs. 25.)
Preliminary report on the management of Willamette Valley soils. (Oregon Sta. Bul. 185, pp. 12, fig.1.)

Lysimeter experiments.—II, Records for tanks 13 to 16 during the years 1913 to 1917, inclusive. T. A. Lyon and J. A. Bizzell. (New York Cornell Sta. Mem. 41, pp. 45–93.)
Guide to soil experiment fields (Missousi Sta. Dept. Guide 1, pp. 12, pl. 1, figs. 2.)
Manual of the principal soils of Missouri. M. F. Miller and H. H. Krusekopf. (Missouri Sta. [Pamphlet], pp. 15, fig. 1.)

FERTILIZERS

Fertilizer experiments. C. P. Blackwell and T. S. Buie. (South Carolina Sta. Bul. 209, pp. [77], figs. 52.)
The comparative value of different forms of lime. A. G. McCall. (Maryland Sta. Bul. 242, pp. 157–166, fig. 1.)
Liming with high magnesium v. high calcium limes. B. L. Hartwell. (Rhode Island Sta. Bul. 186, pp. 19.)
The effect of rock phosphate upon the corn possibility of the phosphoric acid of the soil. G. S. Fraps. (Texas Sta. Bul. 289, pp. 17, figs. 5.)
Thirty years' experience with sulfate of ammonia. F. W. Morse. (Massachusetts Sta. Bul. 204, pp. 83–98, pls. 2.)
Availability of some nitrogenous and phosphatic materials. G. S. Fraps. (Texas Sta. Bul. 287, pp. 16, figs. 2.)
Decomposition of green manures at different stages of growth. T. L. Martin. (New York Cornell Sta. Bul. 406, pp. 135–169, figs. 10.)
Sweet clover for nitrate production. A. L. Whiting and T. E. Richmond. (Illinois Sta. Bul. 233, pp. 253–267, fig. 1.)
The substitution of stable manure by fertilizers, green manures, and peat. B. L. Hartwell and F. K. Crandall. (Rhode Island Sta. Bul. 188, pp. 23, fig. 1.)
The use of fertilizers on dairy farms. A. R. Whitson and G. Richards. (Wisconsin Sta. Bul. 341, pp. 24, figs. 4.)
Fertilizers for Maryland soils. A. G. McCall. (Maryland Sta. Bul. 247, pp. 117–151, figs, 7.)
Changes in the composition and cost of fertilizers in New York from 1914 to 1921. L. L. Van Slyke. (New York State Sta. Bul. 493, pp. 12.)
Testing fertilizers for Missouri farmers, 1921. F. B. Mumford. (Missouri Sta. Bul. 192, pp. 70, fig. 1.)

FIELD CROPS

Alfalfa.

Alfalfa experiment. M. A. Beeson, A. Daane, and D. R. Johnson. (Oklahoma Sta. Bul. 138, pp. 18, figs. 3.)
Alfalfa culture (Holly Springs Branch Station). C. T. Ames. (Mississippi Sta. Circ. 43, pp. 4.)
Irrigation of alfalfa. W. L. Powers and W. W. Johnston. (Oregon Sta. Bul. 189, pp. 36. figs. 22.)
Alfalfa production under irrigation. G. Stewart. (Utah Sta. Circ. 45, pp. 48, figs. 14.)
Fertilizers for alfalfa in eastern Kansas. L. E. Call, R. I. Throckmorton, C. C. Cunningham, and B. S. Wilson. (Kansas Sta. Bul. 226, pp. 30, figs. 3.)

Corn.

Production of new strains of corn for New York. C. H. Myers, H. H. Love, and F. P. Bussell. (New York Cornell Sta. Bul. 408, pp. 205–268, figs. 12.)
Characters connected with the yield of the corn plant. W. C. Etheridge. (Missouri Sta. Research Bul. 46, pp. 17, fig.1.)
Correlation between the yields and prolificness of corn varieties grown in Mississippi. H. B. Brown and J. F. O'Kelly. (Mississippi Sta. Circ. 40, pp. 4, figs. 2.)
The effect of a varying supply of nutrients upon the character and composition of the maize plant at different periods of growth. F. L. Duley and M. F. Miller. (Missouri Sta. Research Bul. 42, pp. 66, figs. 25.)
Varieties of corn in Kansas. C. C. Cunningham and B. S. Wilson. (Kansas Sta. Bul. 227, pp. 40, figs. 9.)
Corn in Missouri.—II, Field methods that increase the corn crop. C. A. Helm. (Missouri Sta. Bul. 185, pp. 20, figs. 4.)

Corn—Continued.

Planting rates and spacing of corn, with tables for practical use. C. A. Mooers. (Tennessee Sta. Bul. 124, pp. 31–43.)
Corn experiments in south central Montana.—Results from the experimental dry farm, Huntley, Montana. A. E. Seemans. (Montana Sta. Bul. 140, pp. 24, figs. 7.)
Corn growing in New Jersey. G. W. Musgrave. (New Jersey Stas. Circ. 128, pp. 22, figs. 13.)

Cotton.

Cotton experiments. H. B. Brown and J. F. O'Kelly. (Mississippi Sta. Bul. 205, pp. 16, figs. 2.)
Cotton variety experiments, 1912–1920, Substation No. 7, Spur, Tex. G. F. Freeman and R. E. Dickson. (Texas Sta. Bul. 288, pp. 17.)
Why not plant home-grown cotton seed? H. B. Brown. (Mississippi Sta. Circ. 37, pp. 3.)

Forage Crops—Clovers—Grasses.

Hubam clover. F. S. Wilkins. (Iowa Sta. Circ. 76, pp. 16, figs. 7.)
Sweet clover in Arizona. S. P. Clark. (Arizona Sta. Circ. 34, pp. 7.)
Sweet clover. R. K. Bonnett and H. W. Hulbert. (Idaho Sta. Circ. 22, pp. 14, figs. 3.)
Sweet clover. C. R. McGee. (Michigan Sta. Spec. Bul. 113, pp. 14, figs. 6.)
Sweet clover. C. R. McGee. (Michigan Sta. Circ. 46, pp. 4, figs. 2.)
The pigeon pea (*Cajanus indicus*): Its culture and utilization in Hawaii. F. G. Krauss. (Hawaii Sta. Bul. 46, pp. 23, pls. 5, fig. 1.)
Para and paspalum: Two introduced grasses of Guam. G. Briggs. (Guam Sta. Bul. 1, pp. 44, pls. 6.)
Sudan grass in Arizona. R. S. Hawkins. (Arizona Sta. Circ. 35, pp. 5, figs. 2.)
Rhodes grass in Arizona. S. P. Clark. (Arizona Sta. Circ. 36, pp. 3.)
Sunflowers, their culture and use. A. F. Vass. (Wyoming Sta. Bul. 129, pp. 75–107, figs. 2.)
The culture and feeding of Russian sunflowers. G. R. Quesenberry, C. C. Cunningham, and L. Foster. (New Mexico Sta. Bul. 126, pp. 20, figs. 6.)
Management of meadows and pastures. G. L. Shuster. (Delaware Sta. Bul. 130, pp. 16, figs. 3.)

Potatoes.

Potato growing in Iowa as affected by temperature. A. T. Erwin and R. A. Rudnick. (Iowa Sta. Bul. 206, pp. 71–84, figs. 10.)
Further studies on the effect of missing hills in potato fields and on the variation in the yield of potato plants from halves of the same seed tuber. F. C. Stewart. (New York State Sta. Bul. 489, pp. 52, figs. 3.)
Some phases of breeding work and seed production of Irish potatoes. W. J. Young. (South Carolina Sta. Bul. 210, pp. 20, figs. 4.)
Seed potato improvement. G. R. Hyslop. (Oregon Sta. Circ. 25, pp. 8, fig. 1.)
Seed potatoes for Connecticut. W. L. Slate, jr., and B. A. Brown. (Connecticut Storrs Sta. Bul. 107, pp. 51–56, fig. 1.)
Seed studies with Irish potatoes. J. T. Rosa, jr. (Missouri Sta. Bul. 191, pp. 32, figs. 5.)
Seed potatoes for better yields. J. T. Rosa, jr. (Missouri Sta. Circ. 106, pp. 8, figs. 3.)
Potato seed experiments: Whole small tubers *v.* pieces of large tubers of the same plant. F. C. Stewart. (New York State Sta. Bul. 491, pp. 30.)
Do whole small potatoes make good seed? J. D. Luckett and F. C. Stewart. (New York State Sta. Bul. 491, pop. ed., pp. 7, fig. 1.)
Potato growing in New Jersey. W. H. Martin. New Jersey Stas. Circ. 140, pp. 31, figs. 13.)
Potatoes in South Dakota. A. T. Evans, G. Jansen, and M. Fowlds. (South Dakota Sta. Bul. 196, pp. 373–415, figs. 13.)

Sweet potatoes.

Sweet potatoes. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 49, pp. 8.)

Sweet potatoes—Continued.

Sweet potato fertilizer experiments at Substation No. 2, Troup. W. S. Hotchkiss. (Texas Sta. Bul. 277, pp. 7, fig. 1.)
The sweet potato for south Mississippi. E. B. Ferris and F. B. Richardson. (Mississippi Sta. Bul. 206, pp. 20.)
Sweet potato storage in Delaware. T. F. Manns. (Delaware Sta. Bul. 127, pp. 64, figs. 47.)

Sorghum.

Shelling percentage in grain sorghum. A. B. Conner and R. E. Karper. (Texas Sta. Bul. 294, pp. 11, figs. 2.)
Type and variability in Kafir. A. B. Conner and R. E. Karper. (Texas Sta. Bul. 279, pp. 14, figs. 6.)
Hegari in Arizona. G. E. Thompson. (Arizona Sta. Circ. 33, pp. 4, fig. 1.)

Soybeans.

Soybeans. E. J. Kinney and C. Roberts. (Kentucky Sta. Bul. 232, pp. 25–58, fig. 1.)
Productive methods for soybeans in Missouri. W. C. Etheridge and C. A. Helm. (Missouri Sta. Bul. 195, pp. 33, figs. 13.
Soybeans in South Dakota. A. T. Evans and M. Fowlds. (South Dakota Sta. Bul. 193, pp. 317–324.)

Sugar-producing plants.

Sugar beet growing in Michigan. J. F. Cox and E. B. Hill. (Michigan Sta. Spec. Bul. 106, pp. 23, figs. 20.)
Sugar cane for sirup making. E. B. Ferris. (Mississippi Sta. Bul. 199, pp. 20.)
Sugar cane in St. Croix. L. Smith. (Virgin Islands Sta. Bul. 2, pp. 23, pls. 2, fig. 1.)

Tobacco.

Strains of Standup White Burley tobacco resistant to root rot. W. D. Valleau and E. J. Kinney. (Kentucky Sta. Circ. 28, pp. 16, figs. 6.)
Tobacco in Wisconsin. J. Johnson and C. M. Slagg. (Wisconsin Sta. Bul. 337, pp. 36, figs. 21.)

Wheat.

Varietal trials with spring wheat in North Dakota. T. E. Stoa. (North Dakota Sta. Bul. 149, pp. 55, pls. 2, fig. 1.)
Winter wheat in North Dakota. L. R. Waldron. (North Dakota Sta. Bul. 151, pp. 8.)
Winter wheat in western Nebraska. L. L. Zook. (Nebraska Sta. Bul. 179, pp. 37, figs. 9.)
Acme wheat. A. M. Hume. (South Dakota Sta. Bul. 194, pp. 325–356, figs. 3.)
Productive methods for wheat in Missouri. C. A. Helm and L. J. Stadler. (Missouri Sta. Bul. 188, pp. 40, figs. 8.)
The 1920 wheat, oats, and corn yields from soil experiment fields in Illinois. (Illinois Sta. Circ. 246, pp. 4.)
Garlic and other factors influencing grades of wheat. J. E. Metzger. (Maryland Sta. Bul. 246, pp. 99–116, figs. 3.)

Other cereals.

A classification of the cultivated varieties of barley. R. G. Wiggans. (New York Cornell Sta. Mem. 46, pp. 365–456, pls. 5, figs. 22.)
Desirable qualities of California barley for export. J. W. Gilmore and L. J. Fletcher. (California Sta. Circ. 246, pp. 11, fig. 1.)
Productive methods for oats in Missouri. C. A. Helm and L. J. Stadler. (Missouri Sta. Circ. 105, pp. 16, fig. 1.)
Kanota, an early oat for Kansas. S. C. Salmon and J. H. Parker. (Kansas Sta. Circ. 91, pp. 13, figs. 3.)
Wisconsin oats. B. D. Leith and E. J. Delwiche. (Wisconsin Sta. Bul. 340, pp. 30, figs. 8.)
Rosen rye. F. A. Spragg. (Michigan Sta. Spec. Bul. 105, pp. 11, figs. 8.)

Miscellaneous.

Dependable Michigan crop varieties. J. F. Cox. (Michigan Sta. Spec. Bul. 109. pp. 19, figs. 11.)
Crop rotations for Missouri soils. R. R. Hudelson and C. A. Helm. (Missouri Sta. Bul. 183, pp. 27, figs. 11.)
Thirty years of field experiments with crop rotation, manure, and feritlizers. M. F. Miller and R. R. Hudelson. (Missouri Sta. Bul. 182, pp. 43, figs. 11.)
Fertilizer requirements of rotations, including corn, potatoes, rye, and hay. B. L. Hartwell and S. C. Damon. (Rhode Island Sta. Bul. 185, pp. 39.)
Grain mixtures and root crops under irrigation. P. V. Cardon. (Montana Sta. Bul. 143, pp. 14.)
Dry farm crop production in eastern New Mexico. J. C. Cole. (New Mexico Sta. Bul. 130, pp. 32, figs. 5.)
Experiments in field plat technic for the preliminary determination of comparative yields in the small grains. L. J. Stadler. (Missouri Sta. Research Bul. 49, pp. 78, figs. 4.)

HORTICULTURE

Fruits—General.

Localization of the factors determining fruit bud formation. H. D. Hooker, jr., and F. C. Bradford. (Missouri Sta. Research Bul. 47, pp. 19.)
Studies in orchard management. K. Sax. (Maine Sta. Bul. 298, pp. 53–84, fig. 1.)
Orchard soil management and fertilization. O. M. Morris and R. Larsen. (Washington Sta. Pop. Bul. 121, pp. 23, figs. 2.)
Central wire bracing for fruit trees. L. C. Barnard. (California Sta. Circ. 244, pp. 10, figs. 8.)
Orchard survey of the northeastern district of Colorado. E. P. Sandsten and C. M. Tompkins. (Colorado Sta. Bul. 272, pp. 28.)
Orchard survey of the Arkansas Valley district. E. P. Sandsten and C. M. Tompkins. (Colorado Sta. Bul. 273, pp. 24.)

Apples.

Studies in apple pollination. O. M. Morris. (Washington Sta. Bul. 163, pp. 32, figs. 6.)
Certain responses of apple trees to nitrogen applications of different kinds and at different seasons. H. D. Hooker, jr. (Missouri Sta. Research Bul. 50, pp. 18.)
First 15 years of 40-variety apple orchard. Apple selection from high and low yielding parent trees. M. B. Cummings. (Vermont Sta. Bul. 221, pp. 38, pls. 4, figs. 2.)
Hood River apple orchard management with special reference to yields, grades, and value of fruits. G. G. Brown. (Oregon Sta. Bul. 181, pp. 36, figs. 7.)
Apples in north Mississippi (Holly Springs Branch Station). J. C. C. Price and C. T. Ames. (Mississippi Sta. Circ. 41, figs. 2.)

Grapes and small fruits.

Grapes. F. W. Faurot. (Missouri Sta. Circ. 20, pp. 28, figs. 12.)
The home vineyard. L. O. Bonnet. (California Sta. Circ. 231, pp. 12, figs. 4.)
Replacing missing vines. F. T. Bioletti. (California Sta. Circ. 249, pp. 4, fig. 1.)
Vine pruning systems. F. T. Bioletti. (California Sta. Circ. 245, pp. 4, figs. 3.)
Cordon pruning. F. T. Bioletti. (California Sta. Circ. 229, pp. 14, figs. 9.)
Vineyard irrigation in arid climates. F. T. Bioletti. (California Sta. Circ. 228, pp. 4.)
Phylloxera-resistant stocks. F. T. Bioletti, F. C. H. Flossfeder, and A. E. Way. (California Sta. Bul. 331, pp. 79–139, figs. 11.)
Grape production and distribution in western Iowa. T. J. Maney. (Iowa Sta. Bul. 199, pp. 376–399, figs. 10.)

Grapes and small fruits—Continued.

Grapes in Mississippi. J. C. C. Price. (Mississippi Sta. Circ. 44, pp. 4, figs. 3.)
Small fruit growing in Missouri. H. G. Swartwout. (Missouri Sta. Bul. 184, pp. 27, figs. 6.)
Blackberries of New England.—Genetic status of the plants. A. K. Petersen. (Vermont Sta. Bul. 218, pp. 34, pls. 19.)

Miscellaneous fruits.

The apricot in California. W. L. Howard. (California Sta. Circ. 238, pp 53, figs. 8.)
Harvesting and handling apricots and plums for eastern shipment. W. P. Duruz. (California Sta. Circ. 239, pp. 24, figs. 21.)
Harvesting and handling California cherries for eastern shipment. W. P. Duruz. (California Sta. Circ. 232, pp. 19, figs. 14.)
A new test for maturity of the pear.—Pear harvesting and storage investigations (third report). A. E. Murneek. (Oregon Sta. Bul. 186, pp. 28, figs. 9.)
Harvesting and handling California pears for eastern shipment. W. P. Duruz. (California Sta. Circ. 240, pp. 19, figs. 10.)
Harvesting and handling California peaches for eastern shipment. W. P. Duruz. (California Sta. Circ. 241, pp. 21, figs. 13.)
Prune growing in California. A. H. Hendrickson. (California Sta. Bul. 328, pp. 38, figs. 12.)
The olive in Arizona. F. J. Crider. (Arizona Sta. Bul. 94, pp. 399–528, figs. 20.)
Some factors affecting the quality of ripe olives sterilized at high temperatures. W. V. Cruess. (California Sta. Bul. 333, pp. 221–231, figs. 2.)

Fruit products.

Dehydration of fruits. W. V. Cruess and A. W. Christie. (California Sta. Bul. 330, pp. 47–77, figs. 2.)
Some factors of dehydrater efficiency. W. V. Cruess and A. W. Christie. (California Sta. Bul. 337, pp. 277–298, figs. 8.)
Marmalade juice and jelly juice from citrus fruits. W. V. Cruess and L. Singh. (California Sta. Circ. 243, pp. 8, figs. 3.)

Walnuts.

Walnut culture in California. L. D. Batchelor. (California Sta. Bul. 332, pp. 139–218, figs. 33.)
Winter injury to young walnut trees during 1921–1922. L. D. Batchelor. (California Sta. Circ. 234, pp. 5, figs. 3.)

Vegetables.

The home vegetable garden. R. A. McGinty. (Colorado Sta. Bul. 276, pp. 36, figs. 5.)
The home vegetable garden as a business proposition. J. T. Rosa, jr. (Missouri Sta. Bul. 193, pp. 16, figs. 8.)
Vegetable gardening in Oregon. A. G. B. Bouquet. (Oregon Sta. Circ. 23, pp. 43, figs. 12.)
The Robust bean. F. A. Sprague and E. E. Down. (Michigan Sta. Spec. Bul. 108, pp. 11, figs. 5.)
Growing head lettuce in Idaho. C. C. Vincent. (Idaho Sta. Circ. 21, pp. 11, figs. 4.)
Pimento and bell peppers. H. P. Stuckey and J. A. McClintock. (Georgia Sta. Bul. 140, pp. 31–43, figs. 6.)
Breeding mosaic-resistant spinach and notes on malnutrition. L. B. Smith. (Virginia Truck Sta. Bul. 31–32, pp. 135–160, figs. 5.)
Yield and quality in Hubbard squash. M. B. Cummings and W. C. Stone. (Vermont Sta. Bul. 222, pp. 48, pls. 2, figs. 7.)
Better methods of tomato production. J. T. Rosa, jr. (Missouri Sta. Bul. 194, pp. 24, figs. 9.)
Tests of the wilt resistance of different tomato varieties. C. W. Edgerton and C. C. Moreland. (Louisiana Stas. Bul. 184, pp. 24, figs. 8.)
Truck crop investigations.—Relation of pressure to effectiveness in spraying tomatoes. L. B. Smith and H. H. Zimmerley. (Virginia Truck Sta. Bul. 33–34, pp. 163–190, figs. 10.)

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Canning factory tomatoes. H. D. Brown. (Indiana Sta. Bul. 259, pp. 20 figs. 8.)

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Spray and practice outline. C. P. Halligan, R. H. Pettit, and G. H. Coons (Michigan Sta. Spec. Bul. 114, pp. 28, figs. 9.)
Dusting and spraying experiments of 1920 and 1921. W. C. Dutton and S. Johnston. (Michigan Sta. Spec. Bul. 115, pp. 54, figs. 24.)
Spray calendar for apples and quinces. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 132, pp. 4, figs. 3.)
Spray calendar for peaches. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 133, pp. 4, figs. 3.)
Spray calendar for pears. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 134, pp. 4, figs. 3.)
Spray calendar for cherries. T. J. Headlee, M. T. Cook, and A. J. Farley. (New Jersey Stas. Circ. 135, pp. 3, figs. 2.)
Spray calendar for grapes. A. J. Farley, M. T. Cook, and T. J. Headlee. (New Jersey Stas. Circ. 136, pp. 3, fig. 1.)
Selection and treatment of waters for spraying purposes with especial reference to Santa Clara Valley. E. R. DeOng. (California Sta. Bul. 338, pp. 301–314, figs. 2.)
Experiments in dusting *v.* spraying on apples and peaches in Connecticut in 1921. W. E. Britton, M. P. Zappe, and E. M. Stoddard. (Connecticut State Sta. Bul. 235, pp. 207–226, pls. 6, figs. 5.)
Spreading and adherence of arsenical sprays. W. Moore. (Minnesota Sta. Tech. Bul. 2, pp. 50, fig. 1.)
Dusting vegetable crops. H. H. Zimmerley, F. W. Geise, and C. R. Willey. (Virginia Truck Sta. Bul. 35–36, pp. 193–208, figs. 6.)
Laboratory studies of the toxicity of some sulphur fungicides. W. L. Doran. (New Hampshire Sta. Tech. Bul. 19, pp. 11.)
A study of the distribution of hydrocyanic acid gas in greenhouse fumigation. W. H. W. Komp. (New Jersey Stas. Bul. 355, pp. 22, figs. 15.)

FORESTRY

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Preliminary volume tables for second-growth redwood. D. Bruce. (California Sta. Bul. 334, pp. 235–237.)
A white fir volume table. D. Bruce. (California Sta. Bul. 329, pp. 39–45.)
An investigation of the seed of the silver maple (*Acer saccharinum*). R. J. Anderson and W. L. Kulp. (New York State Sta. Tech. Bul. 81, pp. 20.)
Growth of oak in the Ozarks. F. Dunlap. (Missouri Sta. Research Bul. 41, pp. 28, figs. 7.)
Precipitation and the growth of oaks at Columbia, Missouri. W. J. Robbins. (Missouri Sta. Research Bul. 44, pp. 21, pl. 1, figs. 3.)
Working plan for a communal forest for the town of Ithaca, New York. J. S. Everitt. (New York Cornell Sta. Bul. 404, pp. 51–99, figs. 15.)
Forest planting in Michigan. A. K. Chittenden. (Michigan Sta. Spec. Bul. 103, pp. 16, figs. 5.)

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Corn root rot diseases. T. F. Manns and J. F. Adams. (Delaware Sta. Bul. 128, pp. 24, figs. 15.)
A new Ascochyta disease of cotton. J. A. Elliott. (Arkansas Sta. Tech. Bul. 178, pp. 18, figs. 5.)
Comparative resistance of varieties of oats to crown and stem rusts. L. W. Durrell and J. H. Parker. (Iowa Sta. Research Bul. 62, pp. 25-56 + [4], figs. 13.)
Potato diseases in Oregon and their control. M. B. McKay. (Oregon Sta. Circ. 24, pp. 52, figs. 38.)
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Diseases of sweet potatoes. M. T. Cook and R. F. Poole. (New Jersey Stas. Circ. 123, pp. 24, figs. 18.)
Recent investigations on the control of three important field diseases of sweet potatoes. R. F. Poole. (New Jersey Stas. Bul. 365, pp. 39, figs. 10.)
Tobacco wildfire.—Preliminary report of investigations. G. H. Chapman and P. J. Anderson. (Massachusetts Sta. Bul. 203, pp. 67-81, pl. 1.)
The wheat bunt problem in Oregon. D. E. Stephens and H. M. Woolman. (Oregon Sta. Bul. 188, pp. 42, figs. 5.)
Septoria glume blotch of wheat. H. R. Rosen. (Arkansas Sta. Tech. Bul. 175, pp. 17, figs. 4.)

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Apple blister canker and its control. W. O. Gloyer and J. D. Luckett. (New York State Sta. Bul. 485, pop. ed., pp. 12, figs. 8.)
A study of the control of crown gall on apple grafts in the nursery. I. E. Melhus and T. J. Maney. (Iowa Sta. Research Bul. 69, pp. 159-172.)
Pear and apple blight in Montana. D. B. Swingle. (Montana Sta. Circ. 98, pp. 10, figs. 3.)
Peach disease control. J. A. McClintock. (Georgia Sta. Bul. 139, pp. 30, figs. 6.)
Recent studies on peach yellows and little peach. M. A. Blake, M. T. Cook, and C. H. Connors. (New Jersey Stas. Bul. 356, pp. 62, pls. 2, figs. 28.)
The coffee leaf spot (*Stilbella flavida*) in Porto Rico. T. B. McClelland. (Porto Rico Sta. Bul. 28, pp. 12, pls. 4.)
Spraying experiments for the control of pecan scab. D. C. Neal. (Mississippi Sta. Bul. 203, pp. 14, figs. 9.)
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The Botrytis blight of tulips. E. F. Hopkins. (New York Cornell Sta. Mem. 45, pp. 315-361, pl. 1, figs. 29.)

Vegetable diseases.

Bean anthracnose. M. F. Barrus. (New York Cornell Sta. Mem. 42, pp. 97-215, pls. 5, figs. 14.)
The yellows disease of cabbage in southwest Virginia. F. D. Fromme. (Virginia Sta. Bul. 226, pp. 9, figs. 5.)
A Phoma root rot of celery. C. W. Bennett. (Michigan Sta. Tech. Bul. 53, pp. 40, figs. 11.)
The Sclerotinia rot of celery. R. F. Poole. (New Jersey Stas. Bul. 359, pp. 27, figs. 17.)
Controlling downy mildew of lettuce. A. T. Erwin. (Iowa Sta. Bul. 196, pp. 305-328, figs. 8.)
Development and pathogenesis of the onion smut fungus. P. J. Anderson. (Massachusetts Sta. Tech. Bul. 4, pp. 99-133, figs. 6.)
Onion diseases and onion seed production. C. W. Edgerton. (Louisiana Stas. Bul. 182, pp. 20, figs. 9.)
Tomato mosiac. M. W. Gardner and J. B. Kendrick. (Indiana Sta. Bul. 261, pp. 24, figs. 13.)

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Fungicidal action of formaldehyde. I. E. Melhus, J. C. Gilman, and J. B. Kendrick. (Iowa Sta. Research Bul. 59, pp. 355–397, figs. 6.)

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Diseases of bees in Michigan. R. H. Kelty. (Michigan Sta. Spec. Bul. 107, pp. 16, figs. 6.)

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The eelworm disease of red clover. R. H. Smith. (Idaho Sta. Bul. 130, pp. 14, figs. 6.)

Control of the potato leaf hopper. F. A. Fenton and A. Hartzell. (Iowa Sta. Circ. 77, pp. 4, figs. 4.)

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Rose bushes in relation to potato culture. E. M. Patch. (Maine Sta. Bul. 303, pp. 321–344, pl. 1.)

A meadow caterpillar. E. M. Patch. (Maine Sta. Bul. 302, pp. 309-320, pls. 2.)

The grass-feeding frog-hopper or spittle-bug. P. Garman. (Connecticut State Sta. Bul. 230, pp. 325–334, pls. 2, figs. 3.)

Grasshoppers and related insects. A. P. Morse. (Maine Sta. Pamphlet [541-6-21], pp. 6.)

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Plant lice injurious to apple orchards.—III, The delayed dormant spray for the control of rosy and green apple aphids. F. Z. Hartzell and L. F. Strickland. (New York State Sta. Bul. 487, pp. 41, figs. 5.)

Apple aphids controlled with the delayed dormant spray. J. D. Luckett, F. Z. Hartzell, and L. F. Strickland. (New York State Sta. Bul. 487, pop. ed., pp. 8, figs. 2.)

Control of apple red bugs by dusting. P. J. Parrott, H. Glasgow, and G. F. MacLeod. (New York State Sta. Bul. 490, pp. 30, pls. 5.)

Dusting *v.* spraying for red bugs. J. D. Luckett, P. J. Parrott, H. Glasgow, and G. F. MacLeod. (New York State Sta. Bul. 490, pop. ed., pp. 8, pl. 1, fig. 1.)

A destructive bud worm of apple trees (*Haploa lecontei*). H. Garman. (Kentucky Sta. Circ. 25, pp. 11, figs. 5.)

Paradichlorobenzene (p-c-benzene) for controlling the peach-tree borer. A. Peterson. (New Jersey Stas. Circ. 126, pp. 11, figs. 7.)

Codling moth control for certain sections of Colorado. G. M. List and J. H. Newton. (Colorado Sta. Bul. 268, pp. 31, figs. 12.)

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The green June beetle or fig eater. J. J. Davis and P. Luginbill. (North Carolina Sta. Appendix to Bul. 242, pp. 8, figs. 22.)

The life history of the oriental fruit moth in northern Virginia. L. A. Stearns. (Virginia Sta. Tech. Bul. 21, pp. 46, figs. 8.)

Spraying for San José scale. W. J. Baerg. (Arkansas Sta. Bul. 177, pp. 19, figs. 2.)

An explanation of recent failures in San José scale control. W. A. Ruth. (Illinois Sta. Circ. 252, pp. 4.)

The strawberry crown borer (*Tyloderma fragariae*). H. Garman. (Kentucky Sta. Circ. 27, pp. 27–34, figs. 2.)

Eastern strawberry louse. W. J. Baerg. (Arkansas Sta. Tech. Bul. 179, pp. 16, figs. 4.)

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Control of the cabbage maggot. L. G. Schermerhorn and C. H. Nissley. (New Jersey Stas. Circ. 138, pp. 4, figs. 2.)
The bionomics and control of the onion maggot. J. R. Eyer. (Pennsylvania Sta. Bul. 171, pp. 16, figs. 5.)
The onion thrips in Iowa. J. L. Horsfall and F. A. Fenton.* (Iowa Sta. Bul. 205, pp. 53–68, figs. 11.)
The root maggot of radishes, turnips, cabbage, and related vegetables. R. H. Smith. (Idaho Sta. Circ. 24, pp. 3, figs. 2.)

Forest insects.

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The painted hickory borer. E. H. Dusham. (New York Cornell Sta. Bul. 407, pp. 171–203, figs. 2.)

Mosquitos and household insects.

A mosquito manual for use in New Jersey schools. (New Jersey Stas. Circ. 130, pp. 16, figs. 22.)
The mosquitos of New Jersey and their control. T. J. Headlee. (New Jersey Stas. Bul. 348, pp. 229, figs. 133.)
Mosquito survey of Mayaguez. W. V. Tower. (Porto Rico Sta. Circ. 20, pp. 10, pls. 4.)
The control of household insects. W. P. Flint. (Illinois Sta. Circ. 257, pp. 24, figs. 15.)

Stored products insects.

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Insect pests of stored grains and their control. M. H. Swenk. (Nebraska Sta. Circ. 15, pp. 14, figs. 9.)
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Insecticides and fungicides for farm and orchard crops in Massachusetts. E. B. Holland, A. I. Bourne, and P. J. Anderson. (Massachusetts Sta. Bul. 201, pop. ed., pp. 16, pl. 1.)
The preparation of nicotine dust as an insecticide. R. E. Smith. (California Sta. Bul. 336, pp. 261–274.)

Miscellaneous.

The relation of the Kentucky species of Solidago to the period of activity of adult *Cyllene robiniae.* H. Garman. (Kentucky Sta. Research Bul. 231, pp. 22, figs. 6.)
Monograph of the North American species of Deraeocoris (Heteroptera, Niridæ). H. H. Knight. (Minnesota Sta. Tech. Bul. 1, pp. 75–210, figs. 47.)
Attachment of the abdomen to the thorax in Diptera. B. P. Young. (New York Cornell Sta. Mem. 44, pp. 255–306, figs. 77.)
The biology of *Ephydra subopaca* Loew. C. Ping. (New York Cornell Sta. Mem. 49, pp. 561–616, figs. 5.)
Annotated list of Halticini. A. B. Duckett. (Maryland Sta. Bul. 241, pp. 107–155.)
North American Ipidae of the subfamily Micracinae, with description of new species and genera. M. W. Blackman. (Mississippi Sta. Tech. Bul. 9, pp. 62, pls. 5.)
Typha insects: Their ecological relationships. P. W. Claassen. (New York Cornell Sta. Mem. 47, pp. 459–531, figs. 86.)
The crane flies of New York.—II. Biology and phylogeny. C. P. Alexander. (New York Cornell Sta. Mem. 38, pp. 691–1133, figs. 540.)
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The common hawks and owls of California from the standpoint of the rancher. J. Dixon. (California Sta. Circ. 236, pp. 17, figs.13.)

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Chamiza as an emergency feed for range cattle. L. Foster, J. L. Lantow and C. P. Wilson. (New Mexico Sta. Bul. 125, pp. 27, figs. 11.)
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The acid base balance in animal nutrition.—III, Effect of addition of alkal to the ration on growth and well-being of swine. A. R. Lamb and J. M Evvard. (Iowa Sta. Research Bul. 71, pp. 194–208, figs. 4.)
The utilization of calcium compounds in animal nutrition. (Ohio Sta. Bu 347, pp. 99, figs. 2.)

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A comparison of broken ear corn and shelled corn, fed with silage, for fattening steers. E. S. Good and L. J. Horlacher. (Kentucky Sta Circ. 26, pp. 15–26, figs. 2.)
Feeding cottonseed and cottonseed products to range steers. E. B. Stanley. (Arizona Sta. Bul. 93, pp. 484–491, figs. 2.)
Wintering and summer fattening of steers in North Carolina. R. S. Curtis, F. T. Peden, and F. W. Farley. (North Carolina Sta. Bul. 243, pp. 20, figs. 4.)
Shelter and warm water for fattening steers. E. L. Potter and R. Withycombe. (Oregon Sta. Bul. 183, pp. 11, figs. 6.)
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Feeding farm work horses and mules. J. L. Edmonds and W. G. Kammlade. (Illinois Sta. Bul. 238, pp. 411–427, figs. 2.)

Sheep.

Sheep-feeding investigations.—X, Fattening western lambs. 1920–21. J. H. Skinner and C. M. Vestal. (Indiana Sta. Bul. 256, pp. 16, figs. 2; also pop. ed., pp. 8, figs. 2.)
Lamb-feeding experiments, 1920–21. C. W. Hickman, E. F. Rinehart, and A. W. Johnson. (Idaho Sta. Circ. 19, pp. 4.)
Lamb-feeding investigations. 1919–20. A. M. Paterson and H. B. Winchester. (Kansas Sta. Circ. 88, pp. 6, fig. 1.)
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Swine-feeding investigations, 1919–20. E. F. Ferrin and H. B. Winchester. (Kansas Sta. Circ. 89, pp. 10, fig. 1.)
Hog-feeding experiments. J. I. Thompson and E. C. Voorhies. (California Sta. Bul. 342, pp. 371–396, fig. 1.)
Rations for pigs. J. W. Wilson and A. H. Kuhlman. (South Dakota Sta. Bul. 192, pp. 302–316, figs. 4.)
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Field peas for pork production. R. E. Gongwer. (Idaho Sta. Bul. 125, pp. 8, fig. 1.)
Rice bran for fattening hogs. D. W. Williams and O. E. McConnell. (Texas Sta. Bul. 286, pp. 15.)
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Self-feeding swine. W. L. Robison. (Ohio Sta. Bul. 355, pp. 19–50, figs. 7.)

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La crianza de aves en Puerta Rico. H. C. Hendricksen. (Porto Rico Sta. Circ. 19, Spanish ed., pp. 22, figs. 14.)
Poultry experiments, observations, notes, and plans. R. H. Waite. Maryland Sta. Bul. 244, pp. 40, figs. 29.)
Methods of mating poultry. L. S. Dodson. (New Jersey Stas. Hints to Poultrymen, 10 (1921), No. 3, pp. 4, fig. 1.)
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Poultry-breeding contest. R. B. Thompson. (Arizona Sta. Circ. 41, pp. 4.)
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Summer production in the laying pens. R. R. Hannas. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 8, pp. 4, fig. 1.)
Egg-laying characteristics of the hen. J. Dryden. (Oregon Sta. Bul. 180, pp. 96, figs. 26.)
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High quality market eggs: Producing, handling, packing. G. H. Pound. (New Jersey Stas. Hints to Poultrymen, 10 (1921), No. 2, pp. 4, fig. 1.)
Culling, a practical plan to eliminate the nonproducing hen. W. H. Allen. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 9, pp. 4, fig. 1.)
Finishing the pullets. W. P. Thorp, jr. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 11, pp. 4, fig. 1.)
Report of egg-laying contests for 1921. R. R. Hannas. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 5, pp. 4.)
How to candle eggs. W. F. Schoppe. (Montana Sta. Circ. 97, pp. 19, figs. 2.)
Natural incubation and brooding. W. F. Schoppe. (Montana Sta. Circ. 103, pp. 8, figs. 3.)
Artificial incubation. J. E. Dougherty. (California Sta. Circ. 233, pp. 10, figs. 4.)
Poultry housing. J. Dryden. (Oregon Sta. Bul. 179, pp. 22, figs. 15.)
Sanitary practices on the poultry plant. W. C. Thompson and G. W. Hervey. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 4, pp. 4, fig. 1.)
Summer health means winter eggs. G. W. Hervey. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 10, pp. 4.)
Monthly standards for New Jersey poultry farms. W. H. Allen. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 6, pp. 4.)
Control of poultry lice and mites. W. F. Schoppe. (Montana Sta. Circ. 95, pp. 8, figs. 2.)
The business possibilities of poultry keeping. W. C. Thompson. (New Jersey Stas. Hints to Poultrymen, 9 (1921), No. 12, pp. 4. fig. 1.)
Practical facts for the squab raiser. W. C. Thompson. (New Jersey Stas. Hints to Poultrymen, 10 (1922), No. 7, pp. 4, fig. 1.)

Miscellaneous.

Report of progress on animal husbandry investigations in 1920. J. W. Cowen. (Maine Sta. Bul. 299, pp. 85–120, figs. 7.)
The effect on growth of breeding immature animals. F. B. Mumford. (Missouri Sta. Research Bul. 45, pp. 37, pls. 6.)
Dressing and cutting lamb and mutton on the farm. M. D. Helser. (Iowa Sta. Circ. 71, pp. 16, figs. 25.)
Dressing and cutting beef on the farm. M. D. Helser. (Iowa Sta. Circ. 72, pp. 23, figs. 30.)
Directions for the tanning and dressing of furs. J. Dixon. (California Sta. Circ. 237, pp. 5, figs. 3.)

DAIRYING AND DAIRY PRODUCTS

Dairy farming. J. B. Fitch. (Kansas Sta. Circ. 90, pp. 32, figs. 13.)
Studies of dairy cattle. J. J. Hooper. (Kentucky Sta. Research Bul. 234, pp. 91–161, figs. 24.)
Judging dairy cattle. G. C. Humphrey. Wisconsin Sta. Bul. 335, pp. 44, figs. 23.)
Advanced registry testing in Indiana. L. H. Fairchild. (Indiana Sta. Circ. 102, pp. 16, figs. 5.)
Studies in milk secretion.—IX, On the performance of the progeny of Holstein-Friesian sires. J. W. Gowen and M. R. Covell. (Maine Sta. Bul. 300, pp. 121–252, figs. 2.)
Studies in milk secretion.—XII, Transmitting qualities of Holstein-Friesian sires for milk yield, butterfat percentage, and butterfat. J. W. Gowen and M. R. Covell. (Maine Sta. Bul. 301, pp. 253–308, figs. 2.)
Dairy calves.—Consumption of food and gain by different breeds—general notes, feed and care. E. Brintnall. (Mississippi Sta. Bul. 200, pp. 16, fig. 1.)
Wintering dairy heifers. R. E. Hunt. (Virginia Sta. Bul. 225, pp. 15, figs. 5.)
Feeding dairy cattle. M. H. Keeney. (New Jersey Stas. Circ. 127, pp. 38, figs. 7.)
Feeding dairy cattle. T. M. Olson. (South Dakota Sta. Bul. 195, pp. 357–372, figs. 2.)
Feeding standards for milk production. W. B. Ellett, C. W. Holdaway, and W. G. Harris. (Virginia Sta. Tech. Bul. 23, pp. 52.)
Influence of condition on maintenance requirements of dairy cattle. A. C. McCandlish and W. G. Gaessler. (Iowa Sta. Research Bul. 60, pp. 403–420, figs. 6.)
The heavy feeding of milk cows is now profitable. H. A. Ross. (Illinois Sta. Circ. 250, pp. 2.)
A comparison of silage and soiling crops for summer milk production. A. C. McCandlish. (Iowa Sta. Bul. 201, pp. 8.)
Coconut meal as a feed for dairy cows and other livestock. F. W. Woll. (California Sta. Bul. 335, pp. 241–258.)
Preparation of corn for dairy cows. A. C. McCandlish and G. E. Weaver. (Iowa Sta. Bul. 195, pp. 297–304.)
Feeding blackstrap molasses to young calves. R. C. Calloway. (Louisiana Stas. Bul. 180, pp. 22, fig. 1.)
Blackstrap molasses for dairy cattle. E. Brintnall. (Mississippi Sta. Circ. 38, pp. 4.)
The production of clean milk. R. N. Davis. (Arizona Sta. Circ. 37, pp. 12, figs. 12.)
Effect of temperature of pasteurization on the creaming ability of milk. H. A. Harding. (Illinois Sta. Bul. 237, pp. 395–408, figs. 6.)
The measurement of the volume of cream on milk. H. A. Harding. (Illinois Sta. Circ. 249, pp. 16.)
Testing milk, cream, and skim milk for butterfat. J. C. Marquardt. (California Sta. Circ. 230, pp. 11, figs. 7.)
Milking machines.—VI, Leakage from the vacuum pipe line into the pail as a source of contamination of milk. R. S. Breed and J. W. Bright. (New York State Sta. Bul. 488, pp. 19, figs. 9.)
Milking machines.—VII, Further studies on methods of sterilization. A. H. Robertson, M. W. Finch, and R. S. Breed. (New York State Sta. Bul. 492, pp. 36.)
Leaky valves on milking machines contaminate milk. J. D. Luckett, R. S. Breed, and J. W. Bright. (New York State Sta. Bul. 488, pp. 8, figs. 8.)
Germ content of milk.—III, As influenced by visible dirt. H. A. Harding and M. J. Prucha. (Illinois Sta. Bul. 236, pp. 363–391, fig. 1.)
The relation between bacterial counts from milk as obtained by microscopic and plate methods. A. H. Robertson. (New York State Sta. Bul. 86, pp. 21, pls. 5.)
Variations in bacteria counts from milk as affected by media and incubation temperature. G. C. Supplee, W. A. Whiting, and P. A. Downs. (New York Cornell Sta. Mem. 43 pp., 217–247.)
The microscopic study of bacteria in cheese. G. J. Hucker. (New York State Sta. Tech. Bul. 87, pp. 11, pl. 1.)
The type of lactic acid produced by starters and by organisms isolated from them. B. W. Hammer. (Iowa Sta. Research Bul. 65, pp. 115–128.)

The relation between the volatile and total acidity in starters and in cultures of *S. lacticus*. W. A. Cordes and B. W. Hammer. (Iowa Sta. Research Bul. 66, pp. 130–136.)
Volatile acid production of *S. lacticus* and the organisms associated with it in starters. B. W. Hommer. (Iowa Sta. Research Bul. 63, pp. 59–96. + [3].)
The colorimetric hydrogen-ion determination as a means of studying biological changes in dairy products. L. H. Cooledge. (Michigan Sta. Tech. Bul. 52, pp. 20, figs. 4.)
Does carbon dioxide in carbonated milk and milk products destroy bacteria? M. J. Prucha, J. M. Brannon, and A. S. Ambrose. (Illinois Sta. Circ. 256, pp. 8.)
Sources of the flavor in butter. B. W. Hammer. (Iowa Sta. Research Bul. 67, pp. 139–144.)
Burnt or caramel flavor of dairy products. B. W. Hammer and W. A. Cordes. (Iowa Sta. Research Bul. 68, pp. 147–156.)
A study of brown glass milk bottles, with reference to their use in preventing abnormal flavors. B. W. Hammer and W. A. Cordes. (Iowa Sta. Research Bul. 64, pp. 99–111.)

VETERINARY SCIENCE

Preliminary rat virus investigations. (North Dakota Sta. Bul. 155, pp. 4.)
Poisoning from *Bacillus botulinus*.—Cause, prevention, treatment. Z. N. Wyant. (Michigan Sta. Circ. 47, pp. 8.)
Actinomycosis (lump jaw, big jaw, and wooden tongue) in cattle. J. W. Connaway. (Missouri Sta. Bul. 186, pp. 15, figs. 9.)
Infectious abortion in cattle. L. F. Rettger, G. C. White, and L. M. Chapman. (Connecticut Storrs Sta. Bul, 108, pp. 59–88.)
The comparative pathogenicity of several strains of *Bacterium abortus* (Bang). I. F. Huddleson. (Michigan Sta. Tech. Bul. 55, pp. 14.)
Preliminary notes on parasites found in ruminants at municipal abattoir, Baton Rouge, La. G. Dikmans. (Louisiana Stas. Tech. Bul. 183, pp. 13, figs. 12.)
Studies in the diseases of the reproductive organs of cattle. E. T. Hallman. (Michigan Sta. Tech. Bul. 54, pp. 23, pls. 6.)
Internal parasites affecting sheep and goats.—Causes, life history, symptoms, and treatments. D. H. Bennet. (Texas Sta. Circ. 28, pp. 3–16, figs. 9.)
Stomach worms in sheep. J. E. Guberlet. (Oklahoma Sta. Bul. 137, pp. 16, figs. 5.)
Some pests of Ohio sheep. D. C. Mote. (Ohio Sta. Bul. 356, pp. 51–79, figs. 18.)
Infectious abortion in swine. J. W. Connaway, A. J. Durant, and H. G. Newman. (Missouri Sta. Bul. 187, pp. 28, figs. 12.)
Swine dysentery. R. A. Whiting, L. P. Doyle, and R. S. Spray. (Indiana Sta. Bul. 257, pp. 15, figs. 10.)
The hog louse, *Haematopinus suis* Linne, its biology, anatomy, and histology. L. Florence. (New York Cornell Sta. Mem. 51, pp. 637–743, figs. 9.)
A study of poultry diseases. W. C. Thompson and L. S. Dodson. (New Jersey Stas. Bul. 363, pp. 61, figs. 20.)
Tuberculosis of poultry. C. H. Werkman and W. M. Gibbs. (Idaho Sta. Bul. 126, pp. 12, figs. 6.)
The principal stock-poisoning plants of Oregon. W. E. Lawrence. (Oregon Sta. Bul. 187, pp. 3–43, pls. 2, figs. 9.)
Death camas (*Zygadenus paniculatus* and *Zygadenus venenosus*), plants poisonous to sheep and cattle. C. E. Fleming, N. F. Peterson, et al. (Nevada Sta. Bul. 101, pp. 31, figs. 13.)
The poison parsnip or water hemlock (*Cicuta occidentalis*), a plant deadly to livestock in Nevada. C. E. Fleming, N. F. Peterson, et al. (Nevada Sta. Bul. 100, pp. 23, pl. 1, figs. 8.)

AGRICULTURAL ENGINEERING

The Colorado River and Arizona's interest in its development. G. E. P. Smith. (Arizona Sta. Bul. 95, pp. 527–546, figs. 2.)
Farm drainage. W. L. Powers and W. Cretcher. (Oregon Sta. Bul. 178, pp. 47, figs. 33.)
Drainage in the Mesilla Valley of New Mexico. D. W. Bloodgood. (New Mexico Sta. Bul. 129, pp. 37, figs. 22.)

Pump drainage of the University of Wisconsin marsh. G. R. B. Elliott, E. R. Jones, and O. R. Zeasman. (Wisconsin Sta. Research Bul. 50, pp. 32, figs. 15.)
The adobe milkhouse. C. B. Brown. (Arizona Sta. Circ. 38, pp. 4, figs. 3.)
Handy equipment for swine raising. W. G. Kaiser and J. M. Evvard. (Iowa Sta. Circ. 69, pp. 47, figs. 43.)
Hog houses for Nebraska. O. W. Sjogren and I. D. Wood. (Nebraska Sta. Circ. 14, pp. 20, figs. 30.)
Sunshine and sanitation for hog houses. W. A. Foster and J. M. Evvard. (Iowa Sta. Bul. 194, pp. 257–296, figs. 45.)
Poultry houses. W. F. Schoppe. (Montana Sta. Circ. 100, pp. 23, figs. 9.)
Farm-poultry buildings. J. G. Halpin, J. B. Hayes, and O. R. Zeasman. (Wisconsin Sta. Bul. 336, pp. 31, figs. 18.)
Poultry-house equipment. W. H. Allen. (New Jersey Stas. Hints to Poultrymen, 10 (1921), No. 1, pp. 4, fig. 1.)
Use of wooden constructed fire-heated hotbeds for production of sweet potato plants. C. L. Isbell and W. D. Kimbrough. (Alabama College Sta. Bul. 217, pp. 6, figs. 3.)
The effect of alkali on Portland cement. (Wyoming Sta. Circ. 16, pp. 4, figs. 2.)

RURAL ECONOMICS AND SOCIOLOGY

Home economics exhibits for county and community fairs. M. Wilkerson. (Illinois Sta. Circ. 247, pp. 24, figs. 8.)
Home economics extension service in Illinois. J. L. Bane. (Illinois Sta. Circ. 248, pp. 18, pl. 1.)
The costs of crop production in Missouri, 1921. B. H. Frame. (Missouri Sta. Bul. 190, pp. 15, figs. 2.)
Farm costs and relative profitableness of seven crops, Twin Falls County, Idaho, 1919–20. B. Hunter and S. B. Nuckols. (Idaho Sta. Research Bul. 2, pp. 24.)
Cost of producing truck in Copiah County, 1921. J. N. Lipscomb and M. E. Andrews. (Mississippi Sta. Circ. 39, pp. 4.)
Costs, profits, and practices of the can-house tomato industry in New Jersey. F. App and A. G. Waller. (New Jersey Stas. Bul. 353, pp. 85, figs. 18.)
The relative cost of making logs from small and large timber. D. Bruce. (California Sta. Bul. 339, pp. 317–333, fig. 1.)
Thousands sign for cooperative marketing. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 8 (1921), No. 46, pp. 8.)
Local cooperative potato marketing in Minnesota. J. D. Black, F. Robotka, and P. L. Miller. (Minnesota Sta. Bul. 195, pp. 88, figs. 7.)
Cooperative livestock shipping in Iowa in 1920. E. G. Nourse and C. W. Hammans. (Iowa Sta. Bul. 200, pp. 401–436, figs. 3.)
Marketing livestock given special attention. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922) No. 47, pp. 8.)
Sell wool cooperatively. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 52, pp. 5.)
Study manner and time to market hogs for best results. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 50, pp. 8.)
The cost of producing milk. H. B. Munger. (Iowa Sta. Bul. 197, pp. 337–352.)
Studies in city milk distribution. S. J. Brownell. (Michigan Sta. Spec. Bul. 111, pp. 24, fig. 1.)
An experiment in improving the milk supply of a city milk plant. L. H. Cooledge and O. T. Goodwin. (Michigan Sta. Spec. Bul. 112, pp. 16, figs. 3.)
Creamery bookkeeping. M. Mortensen. (Iowa Sta. Circ. 68, pp. 20, figs. 11.)
An economic study of farm tractors in New York. W. I. Myers. (New York Cornell Sta. Bul. 405, pp. 51–134, figs. 12.)
Graphic presentation of statistics of farm products. H. E. Selby. (Montana Sta. Circ. 99, pp. 46, pl. 1, figs.48.)
A graphical presentation of the financial phases of feeding experiments. H. H. Mitchell. (Illinois Sta. Bul. 234, pp. 271–327, pl. 1, figs. 15.)
Farm-management studies.—Lessons from irrigated farms in the Billings region. E. L. Currier. (Montana Sta. Circ. 101, pp. 36, figs. 28.)
Iowa farm-management surveys in Blackhawk, Grundy, and Tama Counties. H. D. Munger. (Iowa Sta. Bul. 198, pp. 355–375b.)

Farm tenantry in the United States. W. B. Bizzell. (Texas Sta. Bul. 278, pp. 408.)
Methods of renting land in Ohio. J. I. Falconer. (Ohio Sta. Bul. 348, pp. 101–130, figs 6.)
The Federal farm-loan system. I. Wright. (Illinois Sta. Circ. 259, pp. 20.)
The farmer's credit. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 48, pp. 9.)
Farmer must solve his own credit problems. A partial list of products which farmers have for sale. (North Carolina Sta. Farmers' Market Bul., 9 (1922), No. 51, pp. 6.)
Farm development studies in northern Minnesota. C. G. Worsham and A. Boss. (Minnesota Sta. Bul. 196, pp. 47, figs. 4.)
Rural primary groups. J. H. Kolb. (Wisconsin Sta. Research Bul. 51, pp. 81, figs. 22.)
French Creek as a rural community. A. J. Dadisman. (West Virginia Sta. Bul. 176, pp. 23, figs. 27.)

REPORTS, PERIODICALS, REGULATORY PUBLICATIONS, AND PUBLICATION LISTS

Reports.

Report of the Alaska Agricultural Experiment Stations, 1920. C. C. Georgeson et al. pp. V+75, pls. 7.
Report of the director of the agricultural experiment station, 1921. C. M. Haring. (Rpt. Col. Agr. and Agr. Expt. Sta., Univ. California, 1921, pp. 15–166.)
The thirty-fourth annual report of the [Colorado] Agricultural Experiment Station, 1921. C. P. Gillette et al. pp. 43.
Forty-fourth annual report of the Connecticut [State] Agricultural Experiment Station, New Haven, Conn., for the year 1920. E. H. Jenkins et al. pp. XVI+377, pls. 20, figs. 114.
Report of the director for the year ending October 31, 1921. E. H. Jenkins. (Connecticut State Sta. Bul. 232, pp. 18.)
Annual report of the director for the fiscal year ending June 30, 1920. C. A. McCue et al. (Delaware Sta. Bul. 126, pp. 28.)
Annual report of the director for the fiscal year ending June 30, 1921. C. A. McCue et al. (Delaware Sta. Bul. 129, pp. 30.)
Thirty-fourth annual report, Georgia Experiment Station, for the year 1921. H. P. Stuckey. pp. 26, figs. 6.
Report of the Guam Agricultural Experiment Station, 1920. C. W. Edwards et al. pp. 79, pls. 8.
Report of the Hawaii Agricultural Experiment Station, 1920. J. M. Westgate et al. pp. 72, pls. 10, figs. 2.
Work and progress of the agricultural experiment station for the year ended December 31, 1921. E. J. Iddings. (Idaho Sta. Bul. 129, pp. 15.)
Thirty-fourth annual report of the Purdue University Agricultural Experiment Station, Lafayette, Indiana, for the year ending June 30, 1921. G. I. Christie. pp. 56, figs. 31.
Annual report for fiscal year ending June 30, 1920, Agricultural Experiment Station, Iowa State College of Agriculture and Mechanic Arts. C. F. Curtiss and W. H. Stevenson. pp. 64.
Director's report [Kansas Agricultural Experiment Station], 1919–20. F. D. Farrell. pp. 99.
Thirty-second annual report of the Kentucky Agricultural Experiment Station for the year 1919, Part II. pp. 372+29–38+III, pls. 4, figs. 12.
Thirty-third annual report of the Agricultural Experiment Station of the University of Kentucky for the year 1920, Part I. T. Cooper. pp. 49.
Thirty-third annual report of the agricultural experiment stations of the Louisiana State University and Agricultural and Mechanical College for 1921. W. R. Dodson. pp. 32.
The thirty-fourth annual report of the University of Maryland Agricultural Experiment Station, 1921. H. J. Patterson. pp. XIX+186, figs. 38.
Thirty-third annual report of the Massachusetts Agricultural Experiment Station [1920], Parts I and II. S. B. Haskell et al. pp. 60a+144, pl. 1, figs. 14.
Thirty-third annual report of the Experiment Station of the Michigan Agricultural College for the year ending June 30, 1920. R. S. Shaw et al. pp. 227–700, figs. 79.

Reports—Continued.

Twenty-ninth annual report of the [Minnesota] Agricultural Experiment Station, 1921. R. W. Thatcher et al. pp. 117.

Mississippi Agricultural Experiment Station, thirty-fourth annual report for the fiscal year ending June 30, 1921. J. R. Ricks et al. pp. 56.

One year's work [of] the agricultural experiment station for the year July 1, 1920, to June 30, 1921. F. B. Mumford et al. (Missouri Sta. Bul. 189, pp. 64, figs. 18.)

Biennial reports of the Missouri State Fruit Experiment Station, 1915–1920. P. Evans, F. W. Faurot, et al. Rpts. 1915–16, pp. 7; 1917–18, pp. 11; 1919–20, pp. 12, figs. 7.

Twenty-seventh annual report [Montana Agricultural Experiment Station] for the fiscal year ending June 30, 1920. F. B. Linfield et al. pp. 52.

Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1920. pp 16.

Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1921. pp. 20, figs. 2.

Report of the New Hampshire Agricultural Experiment Station for the biennium ending June 30, 1920. (New Hampshire Sta. Bul. 198, pp. 22.)

Report of the director of the New Hampshire Agricultural Experiment Station for the year ending June 30, 1921. J. C. Kendall. (New Hampshire Sta. Bul. 203, pp. 31, figs. 2.)

Forty-first annual report of the New Jersey State Agricultural Experiment Station and the thirty-third annual report of the New Jersey Agricultural Experiment Station for the year ending June 30, 1920. J. G. Lipman et al. pp. XXXII+610, pls. 23, figs. 63.

Thirty-first annual report, Agricultural Experiment Station of the New Mexico College of Agriculture and Mechanic Arts, 1920. F. Garcia. pp. 53, figs. 9.

Thirty-second annual report, Agricultural Experiment Station of the New Mexico College of Agriculture and Mechanic Arts, 1921. F. Garcia. pp. 48.

Thirty-fourth annual report of the New York State College of Agriculture at Cornell University and of the Agricultural Experiment Station, 1921. A. R. Mann. pp. 97+[5].

Thirty-ninth annual report of the New York [State] Agricultural Experiment Station for the year 1920. W. H. Jordan et al. pp. VII+586, pls. 21, figs. 37.

Fortieth annual report [New York State Agricultural Experiment Station] with the director's report for 1921. R. W. Thatcher. pp. 40.

Forty-fourth annual report of the North Carolina Agricultural Experiment Station for the fiscal year ending June 30, 1921. B. W. Kilgore et al. pp. 80.

Fortieth annual report of the Ohio Agricultural Experiment Station for the year ended June 30, 1921. C. G. Williams. (Ohio Sta. Bul. 353, pp. XXX+[5], fig. 1.)

Two years of research (for the biennium ending June 30, 1921). (Pennsylvania Sta. Bul. 170, pp. 32.)

Annual report of the Porto Rico Agricultural Experiment Station, 1920. D. W. May et al. pp. 39, pls. 6.

Thirty-third annual report of the director of the Agricultural Experiment Station of the Rhode Island State College, [1920]. B. L. Hartwell. pp. 15.

Thirty-fourth annual report of the South Carolina Experiment Station of the Clemson Agricultural College for the year ended June 30, 1921. H. W. Barre. pp. 55, figs. 19.

South Dakota Agricultural Experiment Station, annual report of the director for the fiscal year ending June 30, 1921. J. W. Wilson et al. pp. 37.

Thirty-third annual report [Texas Agricultural Experiment Station], 1920. B. Youngblood. pp. 80, figs. 36.

Thirty-first annual report for the year ending June 30, 1921. E. C. Johnson et al. (Washington Col. Sta. Bul. 167, pp. 64.)

New pages in farming.—Annual report of the director, 1920–21. H. L. Russell and F. B. Morrison. (Wisconsin Sta. Bul. 339, pp. 43, figs. 40.)

Thirty-first annual report of the University of Wyoming Agricultural Experiment Station, 1921. A. D. Faville et al. pp. 109–140, fig. 1.

Report of the Cranberry Station for 1919 and 1920. H. J. Franklin. (Massachusetts Sta. Bul. 206, pp. 149–168.)

Reports—Continued.

Special report of the Upper Peninsula Experiment Station. D. L. McMillan and G. W. Putnam. (Michigan Sta. Spec. Bul. 110, pp. 40, figs. 26.)
Report of the Northwest Experiment Station, Crookston [Minnesota], 1920. C. G. Selvig et al. pp. 114, figs. 20.
Report of the Northeast Demonstration Farm and Experiment Station, Duluth [Minnesota], 1920. M. J. Thompson. pp. 28, figs. 5.
Report of West Central Experiment Station, Morris [Minnesota], 1920. P. E. Miller. pp. 36.
Report from Holly Springs Branch Experiment Station for 1921. C. T. Ames. (Mississippi Sta. Bul. 202, pp. 29, figs. 5.)
Report from South Mississippi Branch Experiment Station for 1921. E. B. Ferris and F. B. Richardson. (Mississippi Sta. Bul. 201, pp. 20.)
Report of the Hettinger Substation for the years 1919 and 1920. U. J. Downey. (North Dakota Sta. Bul. 150, pp. 15, figs. 5.)
Twenty-first report of the State Entomologist for 1921. W. E. Britton. (Connecticut State Sta. Bul. 234, pp. 111–204, pls. 16, figs. 6.)
Report of the tree protection examining board for the biennial period ending June 30, 1921. W. E. Britton et al. Miscellaneous notes. E. H. Jenkins. (Connecticut State Sta. Bul. 231, pp. 337–356.)
Digging up facts for New Hampshire farms. J. C. Kendall. (New Hampshire Sta. Bul. 199, pp. 30, figs. 19.)
Thirty years of agricultural experiments in Utah. F. S. Harris and N. I. Butt. (Utah Sta. Circ. 46, pp. 64, fig. 1.)

Periodicals.

Quarterly Bulletin, Michigan Agricultural Experiment Station—
Vol. 3 (1921), No. 4, pp. 117–148, figs. 11.
Vol. 4 (1921), No. 1, pp. 29, figs. 6; No. 2, pp. 35–66, figs 11; (1922), No. 3, pp. 71–113, figs. 13; No. 4, pp. 117–160, figs. 9.
Monthly Bulletin, Ohio Agricultural Experiment Station—
Vol 6 (1921), No. 7–8, pp. 97–128, figs. 7; No. 9–10, pp. 129–160, figs. 9; No. 11–12, pp. 161–191, figs. 16.
Vol. 7 (1922), No. 1–2, pp. 40, figs. 8; No. 3–4, pp. 42–72, figs. 9.
Bimonthly Bulletin, Western Washington Experiment Station, Puyallup, Wash.—
Vol. 9 (1921), No. 3, pp. 33–48, figs. 5; No. 4, pp. 49–64, figs. 6; No. 5, pp. 65–80; (1922), No. 6, pp. 81–100, figs. 4; No. 7, pp. 101–124, fig. 1.
Vol. 10 (1922), No. 1, pp. 22, figs. 8.

Regulatory Publications—Fertilizers.

Fertilizer report for 1921. E. H. Jenkins and E. M. Bailey. (Connecticut State Sta. Bul. 233, pp. 21–109.)
Commercial fertilizers. E. G. Proulx et al. (Indiana Sta. Bul 253, pp. 71, figs. 2.)
Analyses of commercial fertilizers. H. E. Curtis, H. R. Allen, and R. H. Ridgell (Kentucky Sta. Bul. 230, pp. 193–320.)
Commercial fertilizers, 1921. J. M. Bartlett. (Maine Sta. Off. Insp. 101, pp. 61–80.)
Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and A. M. Clarke. (Massachusetts Sta. Control Ser. Bul. 14, pp. 92)
Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and R. W. Swift. (Massachusetts Sta. Control Ser. Bul. 16, pp. 39.)
Fertilizer analyses. A. J. Patten, O. B. Winter, M. L. Grettenberger, and P. O'Meara. (Michigan Sta. Bul. 291, pp. 109.)
Inspection of commercial fertilizers for 1921. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (New Hampshire Sta. Bul. 201, pp. 16.)
Analyses of commercial fertilizers, fertilizer supplies, and home mixtures, 1921. C. S. Cathcart. (New Jersey Stas. Bul. 358, pp. 55.)
Analyses of commercial fertilizers and ground bone. Analyses of agricultural lime. C. S. Cathcart. (New Jersey Stas. Bul. 361, pp. 52.)
Fertilizer registrations for 1922. C. S. Cathcart. (New Jersey Stas. Bul. 364, pp. 29.)
Inspection of commercial fertilizers. P. H. Wessels. (Rhode Island Sta. Ann. Fert. Circ., 1921, pp. 12.)

Regulatory Publications—Fertilizers—Continued.

Analyses of commercial fertilizers. R. N. Brackett and H. M. Stackhouse. (South Carolina Sta. Bul. 208, pp. 48.)

Commercial fertilizers in 1920–21. G. S. Fraps and S. E. Asbury. (Texas Sta. Bul. 280, pp. 22.)

Regulatory Publications—Feeding Stuffs.

Commercial feeding stuffs. E. G. Proulx et al. (Indiana Sta. Bul. 260, pp. 16, figs. 2.)

Commercial feeding stuffs. J. D. Turner, H. D. Spears, and E. L. Jackson. (Kentucky Sta. Bul. 235, pp. 165–301.)

Commercial feeding stuffs, 1920–21. J. M. Bartlett. (Maine Sta. Off. Insp. 100, pp. 21–60.)

Inspection of commercial feedstuffs. P. H. Smith and E. M. Bradley. Massachusetts Sta. Control Ser. Bul. 15, pp. 34.)

Commercial feeding stuffs. A. J. Patten, O. B. Winter, M. L. Grettenberger, and P. O'Meara. (Michigan Sta. Bul. 292, pp. 63.)

Inspection of commercial feeding stuffs. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (New Hampshire Sta. Bul. 200, pp. 43.)

Analyses of commercial feeding stuffs and registrations for 1921. C. S. Cathcart. (New Jersey Stas. Bul. 354, pp. 68.)

A study of the composition of official samples of feeding stuffs and mixtures collected in 1920. L. L. Van Slyke. (New York State Sta. Bul. 482, pp. 23.)

Inspection of commercial feeds. P. H. Wessels and F. P. Gross, jr. (Rhode Island Sta. Ann. Feed Circ., 1921, pp. 12.)

Commercial feeding stuffs. B. Youngblood. (Texas Sta. Bul. 281, pp. 204.)

Regulatory Publications—Seeds.

Experiment station regulations under Arizona uniform seed law. (Arizona Sta. Circ. 40, pp. 8.)

How to comply with the Indiana seed law. E. G. Proulx. (Indiana Sta. Circ. 105, pp. 8, figs. 4.)

Seed analyses, 1913–1921. L. H. Pammel and C. M. King. (Iowa Sta. Bul. 203, pp. 27–43.)

Commercial agricultural seeds, 1921. Insecticides and fungicides, 1920 and 1921. W. J. Morse. (Maine Sta. Off. Insp. 102, pp. 81–100.)

Work of the seed inspection laboratory for the year 1920. F. S. Holmes. (Maryland Sta. Bul. 243, pp. 167–186.)

Results of seed tests for 1921. M. G. Eastman. (New Hampshire Sta. Bul. 202, pp 24.)

Results of seed and legume inoculant inspection for 1921. J. G. Fiske. (New Jersey Stas. Bul. 360, pp. 37.)

State laws concerning the sale of seeds and legume inoculants. J. G. Fiske. (New Jersey Stas. Circ. 137, pp. 15, fig. 1.)

Regulatory Publications—Miscellaneous.

Commercial fertilizers, commercial feeding stuffs, agricultural seed. J. L. Hills, C. H. Jones, G. F. Anderson, and A. S. Lutman. (Vermont Sta. Bul. 220, pp. 32.)

Commercial fertilizers, commercial feeding stuffs, agricultural seed. J. L. Hills, C. H. Jones, G. F. Anderson, and A. S. Lutman. (Vermont Sta. Bul. 223, pp. 30.)

Foods and drugs. J. M. Bartlett. (Maine Sta. Off. Insp. 99, pp. 20.)

Analyses of materials sold as insecticides and fungicides during 1921. C. S. Cathcart and R. L. Willis. (New Jersey Stas. Bul. 357, pp. 22.)

Seventh annual report of the creamery license division, 1921. T. H. Broughton. (Indiana Sta. Circ. 103, pp 16, figs. 2.)

Creamery inspection in New Jersey. F. C. Button. (New Jersey Stas. Circ. 129, pp. 16, figs. 4.)

Inspection of lime products used in agriculture. H. D. Haskins, L. S. Walker, and R. W. Swift. (Massachusetts Sta. Control Ser. Bul. 17, pp. 8, fig. 1.)

Fourth and fifth annual reports for the years 1919–1920 by the Oklahoma State Livestock Registry Board. (Oklahoma Sta. Circ. 47, pp. 155, figs. 4.)

Regulatory Publications—Miscellaneous—Continued.

Stallion enrollment.—X, Report of stallion enrollment work for the year 1921 with lists of stallions and jacks enrolled. (Indiana Sta. Circ. 104, pp. 72, fig. 1.)

Publication lists.

A list of books for the farmer's library. (Illinois Sta. Circ. 251, pp. 27.)
Publications available for free distribution. (Idaho Sta. Circ. 20, pp. 2.)

UNITED STATES DEPARTMENT OF AGRICULTURE
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WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1923

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The year 1923 completed 35 years of operation of agricultural experiment stations in the States under the Hatch Act. That act, passed in 1887, did not become effective until the following year, because it was held to provide for but not to carry an appropriation. What it has meant to the organization of agricultural investigation is shown by the fact that it brought into existence experiment stations in 30 States and Territories which had not made provision for such activity, and that it gave definite form and support to several stations which had little more than a paper existence.

COOPERATIVE MAINTENANCE

The maintenance of the experiment stations represents a great cooperative undertaking between the Federal Government and the States, probably the most notable example of joint effort in the support of research to be found in any country or any field of science. Although no State contribution was stipulated, the participation of the States was implied by the fact that only a small percentage of the Federal appropriation could be used for buildings and none of it for land, and the necessity for added funds soon became so apparent that these were gradually provided in most of the States.

In addition to supplying a definite amount of money, provision was made for a central agency in the United States Department of Agriculture to have general supervision of the expenditure of the funds and to promote the interests of the stations, in the furnishing of aids to investigation, and in the stabilizing of conditions essential to productive research. The supervisory and advisory relations thus provided for by Congress was one of the first instances in which the Federal Government attempted to follow its funds into the States to see that they were devoted to the purposes originally intended and to promote that end through the activities of a central office. That the enterprise has been successful is attested by the position which these institutions have attained and by the notable advancement in knowledge of the principles and practices of agriculture in the past third of a century.

Including the stations in Alaska and the insular possessions and some separate State stations, there are now 69 experiment stations in the United States and its outlying Territories and possessions, and of these 56 share in the Federal appropriation.

PROGRESS OF THE STATIONS

There was evidence of continued development during the year, which served to strengthen the stations and place them in the position of influence they formerly occupied. Increased support and a larger opportunity to strengthen their staffs and work was reflected in the demand for better preparation of workers, a further breaking away from conventional methods, and a raising of the standard of investigation to higher levels. As compared with the preceding fiscal year the total resources represented an increase of $1,360,000, and that derived from State appropriation or allotment showed an increase of nearly $638,000. This is highly gratifying in view of the great need for funds which the stations were experiencing, and evidences an increasing appreciation of their work on the part of the States and of the institutions with which they are connected.

The additional support, however, does not mean as much as it would if the growth for the past few years had been a regular one. During and following the war the support of the stations showed small increase, while the cost of operation grew rapidly. There was therefore an accumulated need of keeping abreast of the progress in other directions, and this has hardly yet been met. On the other hand, the new demands on the stations have grown to such an extent that it has usually not been possible to meet them except in a fragmentary way.

Evidence of growth is more strikingly brought out by a comparison of the past decade. Since 1913 the total resources have more than doubled and the amount of the States' support has fully trebled. The number of workers in the stations has increased by one-third, although there has been little or no advance in the direction of a separate station force. In 1913 approximately 47 per cent of the station workers were engaged in teaching or other college duties, and in 1923 the percentage was a little over 49. It is undoubtedly true, however, that there is much less teaching per worker and that it is more restricted to advanced grades, consisting in many cases of graduate work. There has been progress, therefore, in concentrating the energies of the station staff on research and the more advanced phases of teaching.

The regular publications of the stations have increased little in volume, although the number is somewhat larger. There are far less of the popular or extension character, and the publications are to a much larger extent based on the results of station investigations. The volume of work printed in scientific journals has grown greatly. There is no question that the published work of the stations shows a very material advance in fundamental character and originality.

These facts are the more noteworthy because of the interruption due to the war. They show that as a group the stations have resumed the growth and progress which were so evident prior to that time.

The unfortunate effects of inequalities are, however, apparent. A number of the smaller stations which are doing excellent work would be in position to render even larger service if they were more adequately supported. Financial stringency of the States has held down local support, and in some cases this has made it difficult for the stations to hold their best workers, and impossible for them to enter upon lines for which there was great need.

STABILIZING EFFECT OF THE FEDERAL APPROPRIATIONS

The benefit of the Federal appropriations has accrued not alone from the money supplied but from the stimulation which has come with it. These appropriations were responsible, in a large proportion of the States, for the original establishment of the stations, and the limitations surrounding the use of the funds have necessarily led to aid from the States. The supervision exercised, although designed to conserve the Federal funds, has aided in the development of policies which have been applied to all funds. This has had a far-reaching effect, especially in the earlier days, and it has freed the stations from interference detrimental to their efforts.

The Federal oversight has related not only to the actual expenditures but to the provision of conditions under which the moneys could be advantageously used, including a suitable personnel. As the stations grew, the standards and requirements pre-

scribed for those funds were widely applied to the organization as a whole. Hence the stabilizing effect of the Federal appropriations has been out of proportion to their size. They have not been subject to the fluctuations of appropriations in some of the States, and the measure of supervision and the character of the requirements have been uniform. Insistence upon a conservative policy of continuity in work has guarded against frequent shifting to meet temporary demands, and has emphasized the need for special appropriations by the States as these demands became urgent.

In the list of State-supported institutions, stations and substations have come and gone. Their work has grown to a certain point and then frequently suffered relapse. But the stations established under the Hatch Act have all been continued from the time of their organization and have represented a grade and a stability rarely to be found in purely local institutions. Sometimes neither the interest of a State nor the supervision of the Federal funds has proved sufficient to prevent disruption. Occasionally the stations are subject to a type of interference whose ill effects are not alone measured by the damage done at the particular time, but are difficult for the affected station to throw off.

The year 1923 witnessed a case of this kind of unusual severity, which illustrated how powerless public sentiment may be to afford protection. In the spring of that year control of the board of trustees of the Oklahoma Agricultural and Mechanical College was secured by removal of two members and appointment of others, following which the contract with the president of the college was abrogated and he was summarily removed without being permitted to serve out the college year. Following his overthrow a successor was appointed whose suitability was vigorously challenged, and a considerable number of department heads in the college and experiment station failed of reappointment. Others resigned because they believed every condition was against them, and that the tenure of their position was only limited by the ability to find a successor. The director of the station was among the latter, and the position of dean and director was combined to fill the gap. As could hardly be otherwise, the station work and forces were demoralized and its long-time investigations were jeopardized.

As is usual in such cases, the station was the first agency to be affected, and the effects were more far-reaching than in any other branch of the college. The failure of those responsible to realize the damaging effects and the inevitable setback to the agricultural interests of the State was the most discouraging aspect of the situation. This discouragement was intensified by the fact that the experience of the State in the past has failed to teach a lesson. Since 1900 there have been 10 changes in the directorship at the Oklahoma station, which alone illustrates the impossibility of any fixed, continuous policy; and these, with the many changes in the staff, have resulted in projects upon which much money has been spent becoming well-nigh sterile. Little progress could be made in these from one period to another, and the frequent change in leadership sometimes resulted even in losing sight of the original objective.

Eventually public sentiment did assert itself in this case sufficiently to cause another change in the board of trustees for the purpose of rescinding the action of the previous board. The college president, who had been in power only a few weeks, was dismissed, and the new board refused to retain in office several others who had been identified with his administration. This could not undo the harm which had been done, and served for a time to perpetuate the confusion and uncertainty; but it soon became evident that the board was taking steps to remedy matters as far as possible by the selection of a suitable president; and this, with the placing of the institution on a proper fiscal basis, paved the way for reconstruction. This unfortunate situation left no course open to the department except to withhold the Federal funds pending readjustment; but certain amounts of the Federal funds which had been improperly used were refunded, and the station program was revised and placed on a more promising basis. Following this the funds were released in the hope that this experience was sufficient to bring about a realization of the requirements of a successful and efficient station and to increase its immunity to danger from such disrupting influences.

Fortunately, such conditions are very exceptional. For the most part there is understanding of the dangers which may come from disturbing the well-being of the station and either disinclination or apparent hesitation to take any steps which may lead in that direction. There is wide-

spread appreciation of the stations in all the States, with a strong, aggressive support which would resist harmful influence. Almost universally the stations have made steady advancement in the past few years in strengthening their forces and their work and raising the level of their investigation.

STATE ADMINISTRATIVE CONTROL

There has sometimes been apprehension, mainly on theoretical grounds, lest centralized Federal supervision dominate the local authority in the management of federally aided institutions. Curiously enough, this apprehension has found less expression in relation to research than some other branches of activity, although it might well be contended that research is, of all types of activity, the one whose freedom is to be the most carefully guarded. But the purpose of the relationship of the United States Department of Agriculture to the State experiment stations has become so established as apparently to allay apprehension, and often it has been welcomed as supplying an element of restraint from interference of another type.

A few of the States have instituted administrative supervision affecting not only details but extending to essential features of policy. Federal allotments have been budgeted with the other resources for similar purposes, and subjected to the same limitations and rules and the same intimate control. Nothing in the line of Federal control has approached this supervision in degree or character, and the extension of it has come to be looked upon as a menace to the institutions.

One form this control has taken in several States has been the subdividing of appropriations in great detail so as to fix the amounts which might be used for salaries, for labor, for various classes of supplies and apparatus, and even for the support of individual projects. Not alone the total salaries but those of individual workers have been made statutory, and the amount which might be spent on a given project has been fixed in the appropriating act on the basis of estimates made long in advance and covering a biennial period.

Although the control is confined mainly to finances, it frequently affects directly the details of the work. It supersedes the authority of the director of the station, the dean, and even the president of the college, in matters which are of very vital importance. Decisions are made by fiscal agents located at the seat of government, clothed with large authority, but lacking an understanding or appreciation of the special requirements. The type of control to which there is objection is not exerted through an audit, but by the making of regulations and restrictions, by the setting up of procedure which leaves little to the discretion of administrative authorities and which makes small provision for unforeseen emergency, such as is very apt to arise in an experiment station. In one State, for example, after money has been appropriated by the State or received from the Federal Government, no branch of the college may establish a new position, fill a vacancy, or increase a salary, no matter how great the emergency, without recourse to a State board of administration. Unless supplies, equipment, and apparatus have been estimated for in advance, the station may not make purchases necessitated by unforeseen contingencies in connection with the progress of its investigations. This control extends even to the matter of travel, printing, and the kind of matter which may be published.

Numerous States have imposed restrictions on travel, or regulations which operate to take the decision out of the hands of the local authorities. In a number of cases station men can not travel outside the State except on approval of the governor or State administrative officer at the capitol, to obtain which frequently involves much delay. In six States provisions of law require the approval of all printing, as to quantity and the character of the matter, by State authorities not at the college. The unwisdom of such a course when applied to the results of scientific investigation must be apparent if the provision becomes more than a routine procedure. Not only does it make possible the control of the form of publication, the illustrations and tabular matter to be incorporated, and the detail and length of presentation, but it places in the hands of such censors the determination of what may and what may not be published by the station. The latter is exactly what has been done in a number of cases. Manuscripts from the experiment station have been rejected because they were regarded as too technical or were not thought to be in the interest of agriculture, or they have been edited until they failed to meet their purpose. This will be recognized as one of the most serious forms which State supervision could

take, unless it is exercised with the greatest liberality and large reliance is placed upon the judgment of the administrative officers at the institution.

Where the Federal funds are exempt from State supervision they give a measure of freedom in meeting actual requirements. This applies also, for example, to travel outside the State and to publications, some stations doing all of their out-of-State travel and printing all or most of their publications with the Government appropriations. Where permitted, the Federal funds have sometimes been used to supplement the State appropriations for salaries, enabling a class of workers to be retained who would otherwise be lost to the institution. In some cases, however, regulation of expenditures by State officers is becoming so drastic as to hamper the use of Federal funds, which are paid in advance in order that the stations may have a working capital to meet necessities as they arise. Under the law they are paid to the colleges as the institutions designated as the beneficiaries by the States in their original acceptance of the acts.

Although the States undoubtedly have a responsibility as regards the use of the Federal funds and are fully justified in a form of audit which will guard these responsibilities, there would appear to be no warrant for setting up procedure which will interfere with the proper use of these funds under the Federal laws or place the station at a disadvantage in carrying out its plans for research after they have been approved by the constituted station authorities and by this department.

TREND OF THE STATIONS

From one year to another there is little material change to be noticed in the general course of the experiment stations, but from one period to another certain tendencies make themselves apparent. These are developments which may lie within the organization, or they may trace their origin to considerable extent from without, as a result of conditions developing in the parent institutions.

For several years there has been a movement in the direction of sifting the problems of individual stations, a going over of the list of projects with a view to determining their relative importance at the present stage and deciding which should be brought to a close or given a somewhat new direction. This has proved a profitable undertaking for a number of the stations. The taking account of stock has proved helpful in determining just what point has been reached and the prospect and desirability of further continuance. Sometimes such a review brings out the need for some cooperative or supplementary work, and again it may show how the work can best be rounded out for completion.

With respect to the outlying work, the present tendency is in the direction of more temporary facilities, the local studies, whether done by field workers or the experts, to be reinforced by investigations in the laboratories of the main station. This is a notable advance, for it husbands the stations' resources while providing for investigation of problems where they exist in typical form, and makes it possible to serve the State more thoroughly and systematically.

Increasing emphasis is laid on the laboratory side of investigation or study conducted under laboratory control. This serves to supplement and to some extent to replace reliance on gross experiments in which only part of the conditions are known or can be controlled. The broadened and deepened outlook which advance in science has given has shown the complex nature of many problems previously thought to be simple, and has made it possible to view and approach them from different angles. The quick answer which the field experiment or the feeding trial was formerly expected to give has been shown to be subject to variation and less reliable than was assumed. The trend toward fundamental research based on an exact knowledge of conditions and the study of relationships is one of the notable advances in the work of the stations. This trend has been particularly conspicuous in the past few years, even while the stations were laboring under financial stress, and already such research has yielded results whose practical value needs no defense.

There is much more marked attempt to take account of what others are doing and have done, to build on what research has already suggested or taught, and to maintain contacts which will give familiarity with these things. It is only a step from this to arranging for coordination in studying complicated problems, and even to entering into more or less definite cooperation. Cooperation has been promoted by a number of large cooperative projects conducted by this department, some regulatory or repressive, and others involving investi-

gation, which have demonstrated the advantage of cooperation and done much to allay doubt as to its feasibility. Cooperation between the Federal department and the experiment stations has steadily increased and is now of large proportion, involving many thousand dollars and a long list of diverse projects.

No station exists to itself or relies exclusively upon its own efforts in solving the problems it has to meet. Community of interest, which finds expression in a variety of ways, is having a steady influence on the work of the whole group of stations. Attendance at scientific meetings where there is opportunity for comparison of notes, exchange of views, and the enlargement of acquaintance, has been no small factor in attaining this end.

In general, the tendency is to publish the results of research at the stations more promptly than was formerly the case. This is helped by the use of scientific journals, especially in the making of preliminary announcements and reports of progress when a significant stage has been reached. The more scientific results are thus made promptly available to others, and opportunity for criticism or discussion is offered. The increased volume of published work makes for the growth of knowledge and its use over a broader field, and helps toward the fuller solution of questions of practical importance.

The type of station workers required has undergone a steady change. The demand is now almost universal for thoroughly trained men with graduate study which has broadened their view of the field of science and instilled in them the spirit and methods of science. Many of the less mature workers in the stations arrange to go away on leave of absence for advanced study, frequently on favorable terms on the part of their station, and the younger men coming into the work have been led to see that graduate study is essential to their advancement.

Frequently the work of graduate students is fitted into the station investigations. There are many cases where such students are enrolled in the station as graduate assistants, doing part-time work with opportunity for their studies. On the other hand, the graduate work of the colleges with which the stations are connected has been systematized and enlarged. The end sought is in every way desirable.

There are, however, certain possible dangers to be guarded against, such as overreliance upon that class of help and the retardation of established projects. The station can ill afford to be dependent upon such help for its primary functions, although it often may employ graduate students to the mutual advantage of itself and the students. A blending of the experiment station with the graduate school, however, is not implied; undue dependence upon graduate students might soon rob a station of the independence and self-reliance to be looked for in a research institution having its own aims, resources, and responsibilities.

Another factor to be considered in the preservation of station individuality is the union of station administration with that of other branches of the college. Unless provision is made for an officer of experience in charge of research, with time to study the work of the station, to counsel with and promote the efforts of its workers, and to maintain the necessary contacts within the college and outside of it, the station may decline in aggressiveness and unity of purpose. Other branches are aggressive and have within themselves means of keeping their interests before the authorities and the public.

The station is more than an aggregation of independent departments held together by a name. There is a legitimate and useful place for administration in connection with organized research, and the effective use of public funds calls for a type of study of the field which is not supplied by the individual specialists. A trend away from this, with a minimizing of organization and administration, is not in the direction of preparation for larger support and responsibilities.

IMPORTANCE OF LONG-TIME PLANNING

The attempt to work out a general program covering a period of several years has commanded the attention of several stations. The long-time plan was the subject of a report to the Association of Land-Grant Colleges during the year, by its committee on experiment station organization and policy. Its purpose is to anticipate future development in order to organize the whole effort of a station so as to make provision for its essential parts, minimize the danger of premature interruption, and expand in accordance with a studied plan.

Sooner or later every growing institution outlines such a program. No station can do everything it would be desirable to do, but out of the vast

range of possibilities it must select certain lines and subjects which are primarily worthy of attention. This will affect the building up of a personnel and special facilities for research, and it will serve to bring out more definitely the financial needs. By such means a station may express to the authorities of the college and to the public its mature judgment of the field it ought to occupy and what this would involve.

Consciously or unconsciously the individual stations have been evolving such programs with more or less definiteness, which are expressed in a way by their organization and the list of projects they are pursuing. In the past the plans have usually been of shorter range, and to some extent they have reflected the composition of the personnel, the existing facilities and funds. To an extent this may even have been unconsciously reflecting a public demand, a changing view, or personal preference.

Investigation is rarely a matter for this year or next. It requires a considerable period of time, and at the present stage it needs to be projected so as to be thorough and conclusive. It attacks one point after another in the working out of a problem, the attack changing with the progress of the study but not losing sight of the main objective. An illustration is supplied by the Adams fund projects, outlined with a definite purpose and initial plan of procedure, but subject to modification as the study advances, and designed to continue without interruption until a conclusion or a definite stage of advance has been reached.

A station should not fail to be responsive to the needs of its community, but it can not afford to pursue a vacillating course or to have its work represent fragmentary effort. Its program naturally would be related to the matters of primary importance to its locality, and it should not be so formal or fixed as to omit provision for meeting emergency questions. It would not undertake to be a formally crystallized plan, all-comprehensive in its nature and inflexible in its provisions, but would be designed to serve as a general guide in the administration, development, and financing of the institution. It should never be so inflexible as not to admit of improvement by amendment as new workers and new ideas become available to the station, but, on the other hand, it ought not to be interrupted or abandoned because of changes in personnel or as a result of personal preference of workers. Although opportunity should be preserved for the exercise of initiative and reasonably wide range of freedom in research, such a long-time program would encourage the individual by contributing a larger measure of security for his investigation, and would guard against his needs being overlooked in the annual budget and plans. This might give an added feeling of advantage and permanence among workers which would often reduce the frequency of change from one institution to another, especially among the more mature members.

Evidently such a program should be general rather than detailed, and should be subject to revision from time to time as circumstances require. But it would have a substantial background in a broad study of the situation and represent a conscious effort to weigh and adapt the various lines of effort in accordance with their merits and relative importance. It would tend to direct the policy of the station along well-defined lines, and in many cases it would have reference to the station as a whole rather than to separate departments.

The idea of the unity of a station is essential to the making of any well-rounded program. An experiment station can not be viewed merely as an assembly of departments, but rather as a union of effort in which various departments are embraced. These departments are interrelated and drawn together by community of interest in broad questions. Their relationships are more easily discovered and the objective of the station more readily attained if there is encouragement to think beyond the immediate boundaries of individual departments, and this would be an inevitable result of the construction of a long-time program. Moreover, owing to the dependence of stations on one another in working out the agricultural problems of a given region, each institution needs to take into account the activity of other stations in that region. This can be most successfully done if each station has a fairly definite program mapped out for its main lines of research.

One prerequisite in attaining such an end is a definitely assured budget Under a system of annual or biennial appropriations this can not be absolute, but standing appropriations, or apportionments which make for stability, are becoming more common. The cost of making investigations in

a continuous way and on an assured basis of support is far less than by intermittent and uncertain effort, and results are more sure to follow.

VISITATION OF THE STATIONS

The office has maintained the usual close relations with the experiment stations of the country throughout the year. In addition to its correspondence, its approval of Adams fund projects and programs and the examination of the financial reports, it has been brought into direct contact with all of them through official visits of members of the staff. These examinations on the ground have been participated in by the chief and by W. H. Evans, W. H. Beal, E. R. Flint, and J. I. Schulte.

The advantage of this close contact is seen in the intimate view which it gives of the station work and management, enabling a more just interpretation of the use of the Federal funds. It has helped materially to maintain good relations with the individual stations, and to avoid misunderstandings on either side. The attitude of the local institutions and their authorities toward the Federal supervision has been uniformly cordial and helpful in every way.

LEGISLATION AFFECTING THE STATIONS

Legislative action affecting the experiment stations, aside from appropriations and provisions for new buildings, which are noted elsewhere, was not very extensive during the year.

The California Legislature of 1923 transferred the Laboratory for the Biological Control of Insects from the State department of agriculture to the university, and included $50,000 in the general appropriation of the college of agriculture to maintain the work for two years. Provision was also made for an increase in salaries and maintenance of all college and station activities, which was offset in part by a reduction of $40,000 a year in the income from university endowments available for college and station work.

The preceding legislature of Colorado had provided for the grading of fruits and vegetables, which was assigned to the station. This caused some dissatisfaction, and the last legislature passed a law authorizing voluntary grading by the State, and put it in the hands of a special officer directly under the governor. A bill was passed appropriating $10,000 for the purchase of land and equipment for the Greeley Potato Station, which is being managed by the Bureau of Plant Industry, U. S. Department of Agriculture. An appropriation of $4,000 was also granted for the purchase of land and equipment at the Cheyenne Wells branch station.

The 1923 General Assembly of Connecticut increased slightly the appropriations for the State station, for general maintenance, insect-pest control, white-pine blister-rust control, and gypsy-moth control, and doubled, from $5,000 to $10,000 annually, that for the support of the tobacco substation. An increase from $17,500 to $30,000 was made in the annual appropriation for the Storrs station, for maintenance, which will greatly strengthen the work now under way and allow for a small expansion, notably the inauguration of work in agricultural economics.

A recent session of the Delaware Legislature passed a bill authorizing the control of all expenditures for supplies to be vested in a State board of supplies. The annual appropriation of the station was reduced from $20,000 to $17,500.

In Kansas, the responsibility for the enforcement of the fertilizer, feeding stuffs, and livestock remedy laws was transferred from the experiment station to the State board of agriculture, although the chemical analytical work will continue to be done at the station. A new feature was added to the work of the station by the appropriation of $6,000 a year for the current biennium to finance outlying experiment fields in southeastern Kansas. This was secured as a substitute for a proposed new branch station. These fields will be supervised from the main station, and but little overhead expense will be involved, especially for building and equipment. Five fields have been located for soil and crop problems.

In Minnesota, the legislature increased appropriations for work on soils and discontinued those for investigations on drain tile and cornstalk sirup, the above not becoming effective until the fiscal year 1924.

The Montana Legislative Assembly reduced the appropriation for grasshopper control from $3,900 to $500, which was further reduced to $450 when the governor approved the bill. This unfortunately occurred when the State was in the worst grasshopper outbreak it had experienced for 50 years. The legislative assembly for 1923 revised the insect pest law by authorizing the county commissioners to expend and assess back on all county property not to exceed 1 mill,

instead of one-half mill as previously provided.

In New York the legislature of 1923 passed a law whereby, beginning July 1, 1923, the administration of the State station at Geneva passed into the control of the board of trustees of Cornell University and Dr. R. W. Thatcher was made director of both stations, the Geneva station, however, to remain as an individual unit, with its own series of publications. An act was also passed providing for horticultural investigations in the Hudson River Valley, with appropriations for the same, and giving the board of control of the State agricultural experiment station authority to rent suitable land and buildings and to employ the necessary staff. Special appropriations were also made for vegetable research on Long Island.

The last legislature of Oklahoma passed a law placing a registration fee on fertilizers, the greater part of which will come to the station.

New legislation in Oregon included an economic poison law "to provide for the regulation and manufacture and sale of any substance or mixture of substances intended to be used for preventing, destroying, repelling, or mitigating any and all insects, fungi, weeds, or other plant or animal pests, collectively and individually, which may infest or be detrimental to vegetation." The director of the experiment station is made responsible for the administration of this law.

The Texas Legislature, in passing the general appropriation bill, providing financial support for the Texas station system, removed the restrictions and intense itemization which were formerly placed on the bill, greatly improving the situation as to efficient administration. A State board of control was also provided for which also serves as the board of directors for the State eleemosynary institutions. This board has charge of the printing and purchasing for all State institutions, except that the station is exempted in the case of scientific materials. A new substation for the Rio Grande section was provided for with an appropriation of $25,000 a year for two years.

In West Virginia the legislature provided a sum of $5,000 for buildings upon the Reymann Memorial Farm at Wardensville.

The legislature of Wyoming, of 1923, passed a bill creating a new department of agriculture, to have control of State farms; State dairy, food, and oil department; and the State department of immigration, as well as to take on other duties including general police power in matters relating to agriculture. According to the law, the director of the experiment station of Wyoming is a member of the board of agriculture ex officio. A. D. Faville, former director of the station, was appointed first commissioner of agriculture. A law was also passed abolishing the agricultural advisory board, which had previously had control of the State farms. These were turned over to the board of trustees of the University of Wyoming, with an appropriation of $24,000 to operate them during the biennium. This is the final step in placing the so-called State farms branch stations under the management of the director of the experiment station and the board of trustees..

ADDITIONS TO BUILDINGS AND EQUIPMENT

Important improvements in station equipment, including buildings and land as well as scientific apparatus and laboratory supplies, were made during the year. In a number of States new buildings were provided, either wholly for station use or for combined college and station occupancy. The limited land at the disposal of some of the stations was increased by the purchase of additional acreage either adjacent to the station property or as outlying farms. In many cases additional equipment and buildings were provided at the branch stations, and in some States provision was made for additional stations, thus largely extending the opportunities for investigation under varying local conditions. The more important additions to buildings and equipment were as follows:

At the Alabama station a tract of 55 acres was added to the farm and an option was secured on an adjacent farm of 400 acres. New greenhouses for the agronomy department were completed and put in use, a new animal pathology building was nearly finished and partially occupied, and anatomy and clinical buildings were erected.

The Arizona station reported the addition of considerable apparatus and equipment, and extensive additions to the poultry plant, including an incubator cellar, egg-laying contest houses, and breeding houses. Two dwellings and a pump house were also built. At the substation at Yuma a poultry house and yard, corral, and shed were added.

The Arkansas station lost by fire the main barn, dairy barn, and stock-judging pavilion.

In California, at the university farm at Davis, the new dairy industry and horticulture buildings were completed and occupied. An agronomy warehouse, a pomology packing house, a wool laboratory, and a water tank of 100,000 gallons capacity, providing irrigation for 105 acres, were also added. At the Riverside station, greenhouses were erected, and frost protection provided for 60 acres of citrus orchard. The transfer of the Laboratory for the Introduction of Beneficial Insects from the State department of agriculture brought to the university the equipment housed in a six-room laboratory at Whittier.

At the Colorado station, the old chemistry building, destroyed by fire in 1921, was reconstructed on the old foundation, at a cost of $70,000, to be occupied by the station departments of chemistry and botany. An experimental Venturi flume was built at Bellevue, and a small building was rented and equipped as a chemical laboratory at Rocky Ford.

At the Connecticut State station, an experimental tobacco-curing barn was built at Windsor, and two insectaries were constructed at the main station. At the Storrs station, a large shed was built for steers and supplies for pasture experiments.

In Florida 30 acres of land was contributed by the citizens for the tobacco branch station at Quincy, and a brick laboratory costing about $12,000 was completed.

At the Georgia station, the sweet-potato storage house, which was destroyed by fire, was replaced. A greenhouse for plant disease work was constructed during the year.

The Illinois station secured $50,000 for a beef-cattle barn and equipment; and a respiration chamber, to cost $3,500, with equipment, is to be added.

At the Indiana station a farm of 422 acres about 2 miles from the campus was purchased for the animal husbandry department, and the station was given the use for an indefinite period of an 80-acre farm near Salem, in Marshall County. A new poultry building, to cost $8,600, was started, a new sheep barn with feeding pens was constructed, and the house on the horticultural farm was remodeled.

The Iowa station acquired a tract of about 100 acres of fine farm land, adjacent to the dairy barn, for the use of the dairy husbandry section, and a farm of 165 acres southeast of the campus was purchased for use by the horticulture, forestry, landscape architecture, and truck crops sections. New horse and sheep barns, a poultry laboratory building, a hollow-tile hog house, and a model farmhouse on the agronomy farm, to replace one destroyed by fire, were completed during the year. The station barn was destroyed by fire in 1922 with an estimated loss of $25,000.

At the Kansas station the new wing of the agricultural building, to cost $275,000, was nearly completed. The first floor will be occupied by the dairy department, the second by the poultry department, and the third by agricultural economics, and a one-story extension on the court is to be a meat laboratory.

The Kentucky station acquired a considerable tract of land in the eastern part of the State for experimental work in agriculture and forestry, through the gift of E. O. Robinson of Fort Thomas.

Beef-cattle, dairy, and hog barns were completed at the new site of the Louisiana University and station.

The new chemical building for the Massachusetts station was nearly completed. This will house all of the chemical research, the old chemical laboratory being used for control work. Additions to the poultry plant included three unit laying houses for 600 pullets, a cockerel house, and a house for year-old hens, costing from $5,000 to $7,000.

The Michigan station received $400,000 for a new horticultural building, to be partly used for station work. A new piggery, costing $8,500, and a 3,000-bushel capacity root cellar were added to the equipment.

At the Minnesota station, a new dairy building, to cost, with equipment, about $250,000, was under construction and partly occupied for experimental work.

The new biology building at the Mississippi station, costing $250,000 and to be used in part for station work, was nearly completed. Other additions included some minor buildings and repairs on the farm, and a fireproof storage room for publications.

At the Missouri station, the new agricultural building, costing about $200,000, was nearly completed and partly equipped during the year. Agricultural engineering was transferred to the building formerly used by the poultry department. A new beef-cattle barn was completed at a cost of $25,000, and a new and modern

refrigerating machine was installed in the dairy husbandry department.

The new biology building at the Montana station was completed and partly occupied by certain departments of the station. A refrigerating room for controlled constant temperatures was added. Some improvements in buildings were also made at the Horticultural, Judith Basin, and North Montana substations.

A beef-cattle barn with experimental feeding sheds was erected at the Nebraska station, and a cement-floored feed lot was built at the agronomy farm. The poultry plant at the central station was relocated and new buildings erected.

The New Hampshire station added a number of larger pieces of apparatus to the laboratory equipment.

The poultry husbandry building at the New Jersey station was completed and equipped at a cost of $90,000, and was occupied during the year. Several minor buildings were erected, and substantial additions were made to the dairy herd.

At the New Mexico station, a new greenhouse was completed and an implement and storage shed was built on the horticultural grounds.

The new dairy building at the New York Cornell station, to cost, with equipment, $685,000, was nearly completed. A new pomology storehouse, to cost $32,000, and a plant-breeding drying house, to cost $10,000, are to be built. An appropriation of $500,000 was made for a new plant industry building. A tract of 46 acres was purchased for the experimental farm. A 30-acre tract was purchased at the Long Island Vegetable Research Farm, and some repairs were made. A greenhouse was erected costing $16,200, and a laboratory was built and equipped.

A new building for the State board of agriculture was built at Raleigh, N. C., in which offices and laboratories are provided for some of the station staff. The new agricultural building at the college was completed and occupied by certain of the station departments. Various improvements in buildings were made at the Mountain, Piedmont, Tobacco, Edgecomb, and Coastal Plain substations.

The new agricultural building at the North Dakota station was completed and occupied.

At the Ohio station, a new printery was built and 3,242 acres of forest land was purchased. An appropriation of $75,000 was made for a new building to be occupied by the departments of chemistry and entomology, and part of the botany department.

At the Oklahoma station a new sweet-potato storage house was built with a view to making the study of storage diseases a prominent feature.

Two modern egg-laying houses, each to accommodate 300 hens, were constructed at the Oregon station. The station was given increased accommodations in the agricultural building. Considerable equipment was added to the main and branch stations.

At the Pennsylvania station a new beef cattle barn valued at $50,000 was completed during the year, and a new tobacco-curing shed was built and equipped.

The South Carolina station library was remodeled. The State legislature appropriated $25,000 and the Federal Department of Agriculture allotted an equal amount for an office building and insectary for boll-weevil control work at Florence. A six-room office and laboratory building was constructed there.

A greenhouse was completed at the Utah station, and equipped with a set of cement soil-temperature control tanks for use of the department of botany.

At the Vermont station a new refrigerating apparatus costing $5,000 was installed.

At the Virginia station a small barn was remodeled and equipped exclusively for investigations at a cost of about $5,000. A 50-acre tract of land was purchased in Pittsylvania County for experimental purposes, and a stable and tobacco barn were built on the place, the land and buildings costing $9,000. A lysimeter equipment of 63 tanks was completed and put in use.

At the Washington station new hog barns were completed. At the Prosser branch station a two-story house for the farm help and a dairy barn were built. A laboratory for the study of cranberry diseases was established at Sevier.

A new dairy barn was completed at the West Virginia station at a cost of $30,000. A residence was built at the animal husbandry farm at a cost of approximately $6,500.

At the Wisconsin station a section of the greenhouse for plant disease investigations was nearly completed and equipped. The land, 95 acres, heretofore leased for the Hancock branch station, was purchased. New buildings and equipment were provided at the Ashland branch station.

At the Wyoming station a new parasitology and veterinary building, costing about $14,000, and a new poultry building, costing about $12,500, were completed and partially equipped during the year. Various farm buildings and structures were improved and much needed drainage was undertaken. Additional equipment was provided by a special State fund of $3,200 for the horse breeding experiments, in cooperation with the United States Department of Agriculture. A central sewerage system for the buildings on the animal husbandry farm was installed.

REVENUES OF THE STATIONS

The total income of the stations for the year from all sources, excluding the Federal insular stations, was $9,283,653.20. Of this amount, $1,440,000 was from Federal appropriations under the Hatch and Adams Acts, leaving $7,843,653.20 from sources within the State, which included $5,539,077.02 from State appropriations, $373,977 from fees, $1,050,238.55 from sales, $112,415.12 from miscellaneous sources, and $767,945.51 carried over as a balance from the previous year. This is an increase in station resources over last year, exclusive of Federal funds, of $1,368,248.83.

Twenty-seven stations received an increase in State appropriations over the previous year, 14 received a decreased appropriation, and in 9 there was no change in amount. Nine stations received over $200,000, as follows: California station, $558,996.60; New York Cornell, $404,719.12; Minnesota, $356,746.48; Illinois, $334,666.68; Wisconsin, $252,783.69; Ohio, $252,015; Iowa, $250,000; Indiana, $238,991.38; and New York State station, $211,950.55. Ten stations received from $100,000 to $200,000, 13 from $50,000 to $100,000, 4 from $25,000 to $50,000, 8 from $10,000 to $25,000, 5 less than $10,000, and 1 received no State aid. Complete details of the station receipts and expenditures will be found in the tables at the end of the report.

Appropriations for the Alabama station included $7,500 for the work at Auburn and $27,000 for local experiments. Sales and other sources of income amounted to about $6,000.

The Arizona station received a total of $88,171, being an increase for the year of about $21,640.

Appropriations for the Arkansas station were practically the same as for the previous year.

In California the State appropriation for the station at Berkeley was $157,258 and for the substations $401,738.

The State appropriations for the Colorado station totaled about $125,373. The State mill levy for the year amounted to $99,075 for the station. The legislature appropriated $2,000 a year for two years for experiments at Cheyenne Wells.

The Connecticut State station received an appropriation of $10,000 for a new department of soils. The Storrs station received $17,500 for maintenance and $2,000 as a special sheep fund. An appropriation of $14,600 was received for a new dairy barn.

The State support for the Delaware station was $20,000 for the year.

The Florida Legislature made an annual appropriation of $55,000 to the station to carry on work throughout the State, and including special appropriations of $7,500 for pecan investigations, $10,000 for citrus investigations, $13,500 for the tobacco experiment station, and $20,000 for the Everglades station.

The State fund for the Georgia station was $6,813.35.

The Idaho station received an increase from the State of nearly $7,500, giving a total of $17,458.

In Illinois there was an increase in appropriations of nearly $25,000 for the station.

There was an increase in State support of about $24,000 for the Indiana station. The canners' association gave $2,200 for tomato studies.

There was no change in the State appropriation of $250,000 for the Iowa station for the year.

The Kansas station received an allotment of $40,000, plus the salaries of the station staff, totaling nearly $95,000, and representing a decrease of $2,000 as compared with the preceding year.

There was no change in the State appropriation for the Kentucky station, which remained at $50,000.

The Louisiana Legislature has changed its former policy of making specific appropriations to the different branch stations, and now makes a single appropriation for all experimental work. This amounted to $56,637 for the year.

Special appropriations of $5,000 each were made by the Maine Legislature for the Highmoor and Aroostook farms and for animal husbandry investigations, and $10,000 was appropriated annually for two years for general maintenance.

The Maryland station received $54,629 for the central station and $6,943 for the Ridgely substation.

There was a small increase in State funds for the Massachusetts station, which amounted to $107,410 for the year.

The total amount expended for research at the main and branch stations in Michigan from all sources, including the soil survey, was $245,810, of which the substations received $38,780, and the soil survey $10,000.

The Minnesota State appropriations for the main station were about $268,000, and for the substations about $88,700. The Association of Eastern Paint and Oil Dealers gave $1,000 for investigations in growing wheat and flax together, and a local milling company donated $2,000 for a cereal-breeding greenhouse. A fellowship was established by a commercial concern for investigations in the cracker industry and there were special State appropriations for investigations in drainage and sirup making from sweet-corn stalks.

The total State receipts of the Mississippi station were $82,600, of which $15,300 was for the McNeill branch station, $17,000 for the Holly Springs branch station, and $10,000 for the Raymond branch station.

The Missouri station received $36,024 from the State, the total income from all sources, including balances, being $118,456.

The State appropriation for the Montana station was $134,485, being practically the same as for the previous year. The allotment for the central station was $82,845, and for the substations $51,640.

The Nebraska station had State aid amounting to $178,780.

The Nevada station had no increase, the State appropriations being $1,000 per year.

The New Hampshire station received $7,000 from the State, this being an increase of $2,000 over the previous year.

The total State funds for the New Jersey stations were $155,817.

The New Mexico station State appropriation was $7,500, the same as for the previous year.

The total allotments for research at the New York Cornell station amounted to $404,719. The income of the State station was $211,950.

The North Carolina station does not have any direct State support, but it had an allotment of about $188,346 from the State board of agriculture, which includes the support for the branch stations.

The North Dakota station received only $9,593 from the State, but had a balance of $175,691. The total from all sources was $293,232. The legislature failed to appropriate for the soil survey and the appropriation for the demonstration farms was reduced. The paint and varnish manufacturers gave $4,000 for work with flax.

The State appropriation for the Ohio station was $252,015, which has been more than doubled for the next biennium.

The Oklahoma station again had a State appropriation of $10,500, in addition to which $4,000 was appropriated for an experimental feeding shed for beef cattle, $2,500 for a potato and fruit storage house, $1,600 for machine sheds, and $5,000 for poultry houses.

The total revenue of the Oregon station was $203,689, of which $92,000 was from State appropriation.

The Pennsylvania station had a total income of $84,325, the State support being $27,584. There was a special appropriation for the biennium of $6,000 for tobacco investigations. In addition, $3,197 was provided for raisin investigations and $1,152 for yeast studies. About $6,500 of the Adams fund was allotted to the Institute of Animal Nutrition.

The resources of the Rhode Island station, aside from the Federal funds, were $10,325 from the State and a sales fund of $5,582. The State appropriation included $6,300 for an economist on the station staff.

For the year ended December 31, 1923, the South Carolina Legislature appropriated $50,000 for agricultural research, $10,000 for regulatory activities, and $25,000 for boll-weevil control. Sales and other income amounted to about $24,000. The Pee Dee and Coast substations received $50,000.

The State appropriation for the South Dakota station for the year was $14,420. The four substations received $3,250 each.

The State support for the Tennessee station was increased more than $20,000 over the previous year, being $53,973. An appropriation of $5,000 was made for a new greenhouse.

The Texas station received a total income of $305,118, of which $197,985 was from State appropriation, the balance being from Federal and other sources.

The Utah station had an income of $49,662 from the State, making a total income from all sources of $86,650.

The only State income received by the Vermont station was that allotted

for inspection work and expended for that purpose, amounting to $4,150.

State appropriations for the Virginia station amounted to $57,860.

At the Washington station a full millage tax for the support of the institution as a whole was granted by the legislature and a slight increase over the previous year for the support of the main station, which amounted to $105,276, was granted by the board of regents. In addition a special biennial appropriation of $34,000 was made for the irrigation station at Prosser, as well as an appropriation of $9,000 for cranberry investigations.

The West Virginia station received $120,000 from the State, this being the same amount received the previous year.

Expenditures from State funds for research work during the year at the Wisconsin station amounted to $252,783, as compared with $215,000 for the previous year.

The Wyoming station received $12,000 from the State. The University of Wyoming receives 9 per cent of oil royalties on Government lands, amounting to several hundred thousand dollars annually. The station is benefited by the use of these funds not only in the way of improved buildings and equipment for work, but through the fact that the university is able to carry a large proportion of the overhead expenses formerly paid out of station funds.

CHANGES IN PERSONNEL

There were four changes in directorship of the stations during the fiscal year 1923. E. H. Jenkins resigned as director of both the college and State stations in Connecticut, and was succeeded by W. L. Slate, jr. At the New York Cornell station, A. R. Mann relinquished the duties of director, R. W. Thatcher succeeding to the directorship in addition to that of the New York State station. C. T. Dowell resigned as director of the Oklahoma station and was succeeded by M. A. Beeson. At the Wyoming station, A. D. Faville resigned as director and was succeeded by J. A. Hill.

At the Alabama station, L. E. Miles succeeded A. H. W. Povah as associate plant pathologist.

J. J. Thornber, director of the Arizona station, assumed also the duties of dean of the college of agriculture, succeeding D. W. Working. G. E. Thompson, agronomist, resigned and was succeeded by R. S. Hawkins as acting agronomist. R. H. Williams resigned as head of the animal husbandry department and was succeeded by E. B. Stanley as acting head.

V. H. Young was appointed head of the department of plant pathology at the Arkansas station to fill the vacancy caused by the death of J. A. Elliott.

There were a number of changes at the California station. A. W. Sampson was placed in charge of a new department of range management. F. W. Woll, of the animal nutrition department, died. W. H. Chandler was appointed pomologist, and H. E. Erdman and S. W. Shear as associates in rural institutions. A. E. de Fremery, associate in farm management, and I. F. Torrey, associate in chemistry, resigned. The following appointments were made at Davis: C. H. Bisson, chemist; H. A. Jones, associate in olericulture; W. M. Regan, associate in animal husbandry; W. W. Robbins, associate in botany; and J. L. Stahl, associate in pomology.

M. F. Morgan was appointed specialist in soils at the Connecticut State station. G. H. Chapman, research director of the tobacco station at Windsor, resigned, and was succeeded by C. M. Slagg. S. T. Sealy resigned as deputy in charge of mosquito elimination and was succeeded by R. C. Botsford.

At the Idaho station M. R. Lewis succeeded T. C. Mead as associate in agricultural engineering.

The changes at the Illinois station included the appointment of V. W. Kelley as associate in pomology and the resignation of the following: J. A. Detlefsen, chief in genetics; F. F. Elliott and W. J. Roth, associates in farm management; J. H. Hedgcock, associate in farm mechanics; J. B. Rice, associate in swine husbandry; and H. A. Ross, associate in dairy husbandry.

L. C. Kigin resigned as associate in veterinary science and R. H. Carr as associate in animal nutrition at the Indiana station.

A number of changes were reported from the Iowa station. S. A. Beach, head of the department of horticulture, died. C. L. Holmes succeeded E. G. Nourse as chief of the department of agricultural economics and P. L. Miller was added to the department as assistant chief. E. W. Lindstrom was appointed head of the new department of genetics. W. H. Stevenson, head of the department of farm crops and soils, returned from a year's leave with the International Institute of Agriculture at Rome. C. J. Drake was appointed head of the department of entomology. J. M.

Shaw was appointed assistant chief in dairy husbandry, succeeding J. Waddell; R. L. Parker, assistant chief in apiculture, succeeding O. W. Park; and W. C. Calvert, assistant chief in truck crops, succeeding A. W. Rudnick. F. H. Culley, chief in landscape architecture, resigned.

At the Kansas station C. O. Swanson succeeded L. A. Fitz as head of the department of milling industry. A. M. Paterson and H. B. Winchester, associates in the department of animal husbandry, resigned, as did R. L. Hensel, associate in pasture management.

Changes at the Massachusetts station included the appointment of G. E. Gage as head of the department of veterinary science to succeed J. B. Paige, deceased. F. A. Hays was appointed research professor of poultry husbandry. J. L. Bailey succeeded A. P. French as investigator in pomology.

At the Michigan station V. R. Gardner was appointed head of the department of horticulture to succeed C. P. Halligan, who was transferred to the head of the department of landscape gardening. F. C. Bradford and G. E. Starr were appointed associates in horticulture.

H. W. Vaughan was appointed in charge of beef-cattle husbandry at the Minnesota station.

E. Barnett, head of the department of animal husbandry at the Mississippi station, was transferred to the teaching staff and was succeeded as head of the department by G. S. Templeton. C. J. Goodell was appointed assistant agricultural economist. R. W. Lobdell, zoologist, was put wholly on station time.

At the Missouri station V. R. Gardner resigned as head of the department of horticulture and was succeeded by T. J. Talbert. A. G. Hogan succeeded C. R. Moulton as head of the department of agricultural chemistry.

Changes at the Montana station included the resignation of W. F. Schoppe as head of the department of poultry husbandry.

At the New Jersey stations, W. M. Regan, dairy husbandman; M. T. Cook, plant pathologist; and F. App, agronomist, resigned. J. W. Bartlett was appointed dairy husbandman.

J. C. Overpeck was appointed head of the agronomy department at the New Mexico station, and A. L. Walker succeeded J. H. Bardsley as poultryman.

The principal changes at the New York Cornell station, in addition to the change in directorship, already noted, were the appointment of A. J. Heinicke as head of the department of pomology to succeed W. H. Chandler, and the resignation of O. B. Kent from the department of poultry husbandry.

At the New York State station H. B. Tukey was appointed associate in horticulture, F. H. Lathrop associate in entomology, and E. V. Shear associate in plant pathology, for research work in the Hudson River Valley.

R. Schmidt was appointed vegetable specialist at the North Carolina station to fill the vacancy caused by the death of L. H. Nelson, and V. W. Lewis was appointed specialist in livestock marketing.

At the North Dakota station A. H. Benton was appointed head of the department of marketing and rural finance.

The more important changes at the Ohio station included the resignation of A. D. Selby, chief of the department of botany, who was succeeded by H. C. Young.

W. A. Craft was placed in charge of the breeding work, in the department of animal industry, and F. B. Cross was appointed associate in horticulture, at the Oklahoma station.

D. C. Mote succeeded F. H. Lathrop as associate entomologist at the Oregon station. R. E. Stephenson was appointed associate soils specialist. J. Dryden, chief in poultry husbandry, resigned.

Changes at the Pennsylvania station included the resignation of C. A. Hunter, of the department of bacteriology. E. B. Forbes assumed the directorship of the Institute of Animal Nutrition.

At the Rhode Island station B. L. Hartwell, the director of the station, relinquished the position as chemist and P. S. Burgess was appointed head of the department. P. H. Wessels resigned as associate chemist. F. R Pember, associate in glasshouse experiments, was granted an extended leave of absence.

Among the changes at the South Dakota station were the resignations of T. H. Wright, jr., associate in dairy husbandry, and A. T. Evans, associate in agronomy.

Appointments at the Virginia station included W. D. Saunders, dairy specialist; C. E. Seitz, head of the agricultural engineering department; T. K. Wolfe, agronomist; S. A. Wingard, associate in plant pathology; and J. J. Vernon, associate agricultural economist.

At the Washington station P. W. Allen succeeded W. I. Nightingale as bacteriologist.

The resignation of A. G. Johnson, associate plant pathologist, is noted at the Wisconsin station.

In addition to the change in directorship at the Wyoming station, already noted, F. S. Hultz succeeded F. A. Hays as head of the department of animal husbandry.

SOME RESULTS OF STATION WORK

SOILS

Acidity.—That the intensity of acidity as determined by the hydrogen-ion concentration bears in general no direct or simple relation to the quantity of acid present in the soil was indicated by studies at the Maryland station. The intensity of acidity in many instances appears to be of greater significance in biochemical processes than is the quantity of acid present. That acid phosphate does not tend to make the soil acid, as is commonly believed, is shown by results of 25 years' cylinder experiments at the New Jersey stations. Plats that had been limed for this period showed a hydrogen-ion concentration of from pH 6.8 to pH 7 and grew better corn than unlimed plats showing a concentration of pH 5.2. Plats that had received ammonium sulphate had a concentration of pH 4.8, and practically nothing will grow on them. Cultures with water extracts from this soil showed that the trouble lies with the soluble aluminum, for if this is corrected crops will grow. Basic slag, lime, or acid phosphate was found to correct this condition by precipitating the aluminum. The condition is also largely corrected by the addition of manure, after which corn makes a fair growth, even with a pH value of 5.1.

The Michigan station has observed that the natural weathering of soils leaves them in layers or horizons of varying acidity. The second layer, just beneath the surface, is much more acid than the surface, but this depends upon the climate, drainage, and vegetation. The third layer is one of concentration, the reaction depending on conditions, whereas the second layer is one of leaching. Even in limestone soils the second layer may be acid.

The colloidal clay of an acid soil, according to the Missouri station, appears to be a true acid, which when neutralized gives a characteristic end point, forming a colloidal salt when the concentration of the hydroxyl ions becomes sufficiently great.

Soils high in organic matter did not respond to liming as much as equally acid soils low in organic matter in experiments at the Indiana station.

In experiments at the Wisconsin station seeds germinated at acidities too strong for seedling plants, and the latter were more sensitive to acids than older plants. Alfalfa and clover made maximum growth and produced most nodules at a hydrogen-ion concentration of pH 7 and pH 8—that is, near neutrality. Alsike and red clover grew better with an acid reaction of pH 5 to pH 6 than did alfalfa, and alsike clover withstood an alkaline reaction better than alfalfa. Oats made a maximum growth at about pH 6 and wheat at pH 6 to 7. After 75 days in soils of different degrees of acidity, alfalfa nodule bacteria were dead in a pH 5 concentration, red clover bacteria with pH 4.5 to 4.7, and soybean bacteria with pH 3.5 to 3.9. The texture of the soil exerted no appreciable influence. The results indicate the necessity of frequent inoculation and liming of acid soils.

The acidity of muck soils was found by the North Carolina station to be due, to some extent at least, to the oxidation of the nitrogenous organic matter. The failure of heavy applications of lime to neutralize all of the acidity can be ascribed to the acceleration of this oxidation process by the lime applied.

The Arkansas station found that on acid soils treated with finely ground rock phosphate, oats were relatively richer in phosphoric acid than those grown on neutral soil. Applications of lime reduced the amount of phosphoric acid which the plant obtained from the soil.

Alkali.—Leaching experiments at the Utah station showed that soil containing sodium carbonate leaches very slowly and, after leaching, is in a bad state of tilth. Those containing sodium chloride leached more readily but were also left in a bad state of tilth, while those containing sodium sulfate leached rapidly and the soil was left in a fair state of tilth. The solubility of lime was increased by the presence of alkali in the soil, and the proportion in which calcium and magnesium was rendered soluble in some soils makes it appear probable that at times a toxic calcium-magnesium ratio may occur. Phosphorus, potassium, and nitrogen were leached from the soil in much larger quantities in the presence of alkali salts

than in their absence. The results indicate that the long unproductive period following the drainage of alkali soil is due to two factors, (1) the removal with the alkali salts of much of the readily available plant food, thus requiring a period of further weathering before sufficient plant food is available for crop production, and (2) the poor state of tilth of the drained soil, with possibly, at times, a toxic lime-magnesia ratio.

Adobe soils containing large amounts of alkali become impervious, according to the New Mexico station, when leached with pure water, and hence it is not possible to remove toxic amounts of alkali from such soils by irrigation alone. Sodium chloride is the constituent most readily removed by leaching. Soluble phosphoric acid, when added as a fertilizer, was not leached out by irrigation water, and soluble compounds of potassium and nitrogen were not removed so readily as the common alkali salts but more so than phosphorus.

The California station found that if the water table of the soil was low, 40 feet or more, plants withstood a fairly high degree of alkali in the irrigation water, there being no accumulation of salts at any point, because of the downward movement of the solution. The salts, however, did not move with like rapidity by capillarity. In attempts to reclaim impermeable land, calcium nitrate gave good results, as did sulphuric acid; but nitrate of soda brought about very unfavorable conditions.

In experiments at the Idaho station various combinations of sodium chloride, carbonate, and sulfate, and especially the carbonate, showed a certain stimulating effect on the second crop after application of the alkaline salts. Similar stimulation of the ammonifying and nitrifying organisms was also observed, with larger quantities of the carbonate than the crops could tolerate. Treatment of alkali spots, locally known as "slick spots," where the principal trouble is evidently imperviousness to water, showed that sulfuric acid flocculated the colloidal matter and improved the percolation. Sulfur and gypsum also improved it, but somewhat more slowly than the acid. Aluminum sulfate was an effective flocculent.

Land treated for alkali will rapidly go back to its original condition if treatment is discontinued, according to the Arizona station. With a constant percentage of 0.2 of sodium carbonate, it was found that tolerance of the alkali by crops was greater in heavy than in light soils. In tests of neutralizing the alkalinity with various acids there was a favorable effect with barley from tartaric acid, but with wheat this was not in proportion to the quantity added, although there was some improvement. Ferrous sulfate gave a gradual increase in production in proportion to the quantity used, and this was true to some extent with gypsum. Acetic acid gave some benefit, but not in proportion to the quantity used and not to the same extent as with tartaric acid. The use of free sulfur doubled the yield of wheat, and iron pyrites gave a slight increase in yield.

In experiments at the New Jersey stations sulfur was found to have a marked influence on the permeability of alkali soils. Water readily passed through a soil treated with sulfur, but very little went through the untreated soil, even after prolonged contact. Sulfur-treated soils permitted a rapid capillary rise of water.

Nitrogen.—The New York Cornell station found a rapid disappearance of nitrates from the soil under a growth of timothy. Applications of as much as 900 pounds of nitrate per acre disappeared rapidly. The nitrogen contained in the grass did not account for the disappearance, and evidence obtained from lysimeters indicated that the loss was not due to leaching or to removal from the soil by denitrification. It is believed the nitrate was utilized by various organisms of the soil and was transformed into ammonia or some organic combination. There was a large loss of both nitrogen and lime from bare soil, but the loss of nitrogen in the drainage water from grasslands was negligible. The loss of nitrogen from soils under different fertilizer treatments varied considerably with the type of soil and the form of nitrogen present. Carbonaceous material was also responsible for reduction in nitrates. Timothy was found to reduce nitrates and corn to favor their production. During the later period of crop growth nitrate production decreased.

The presence of nitrates in the soil decreased its nitrogen-fixing power in experiments at the Utah station. Applications of 5 and 15 tons of manure per acre for an 11-year period materially increased the nitrogen-fixing power of the soil, but the increase per ton of manure was greatest with 5 tons. Five-ton applications yearly

for 11 years increased the nitrogen content of the soil by 1,370 pounds, which was 486 pounds more than the nitrogen applied. The application of 15 tons increased the nitrogen content in the first 3 feet 2,248 pounds, which was 450 pounds less than the nitrogen applied. The percentage distribution of the total nitrogen in the first, second, and third foot was respectively 41, 33, and 26.

Lysimeter studies at the New York State station showed that, when large amounts of dried blood were added to a soil growing alfalfa, the plant utilized the nitrogen from this source instead of that assimilated from the air. After five years six times as much nitrate leached out from the legume lysimeters as from the nonlegume. Legumes maintained a much higher nitrogen plane than did nonlegumes.

That sodium nitrate decomposes rapidly in acid soils, more slowly in neutral soils, and still more slowly in alkaline soils was shown by studies at the Oregon station. Sodium nitrate was found by the Massachusetts station to conserve lime in the soil, less escaping in the drainage water when it was applied.

A study of nitrate production at the Missouri station showed that the crop is of significant influence in removing nitrates from the soil and their accumulation is almost reciprocal to the rate and season of crop growth. Early spring tillage, especially plowing, increased nitrate accumulation, but surface tillage lessened it. A straw mulch had a decided effect in holding down nitrate accumulation. Lime was important as a means of increasing nitrate accumulation, whether the soil had been manured or not, but the addition of new organic matter was essential to increase the nitrates, and manured soil accumulated more than unmanured soil. Lime was an outstanding means of increasing nitrification on all crops and for all fertilizer treatments.

Studies with onions, sugar beets, cantaloupes, and corn at the Colorado station showed that nitrates developed rapidly under clean cultivation up to 70 to 100 parts per million in the soil. With barley and clovers, nitrate formation did not exceed 10 or 12 parts per million. Nitrates reached a maximum about July.

On impervious Kirkland upland subsoil the Oklahoma station found that manure with either the oxid or carbonate of lime increased both ammonification and nitrification, manure being less effective in this respect than lime. Nitrification was at a maximum in July and lowest in August, the moisture content of the soil also being lowest in the latter month. Manure gave a little more increase in ammonification than in nitrification and increased the penetration more than lime. It also tended to increase the moisture of the soil, especially in the first 2 or 3 feet.

A depression of nitrification by the long-continued growing of one crop, which rotation relieved somewhat, is reported by the Missouri station. Applications of lime resulted in a decided increase in nitrification, and straw mulch checked nitrate accumulation.

Lime and to a less extent phosphorus favored nitrification in experiments at the Montana station. Sulfur in the form of sulfate stimulated nitrification in certain soils. There appeared to be a correlation between the amount of lime and sulfur necessary in a soil to increase crop production and that necessary to increase nitrification. In greenhouse tests at the Oregon station, liming resulted in increased bacterial activity, including ammonification, nitrification, and nitrogen fixation.

A close correlation was found by the New Jersey stations between soil fertility and the number of bacteria concerned in nitrogen availability and in the reduction and oxidation of carbon compounds. Nitrification was a good index of this, but ammonia fixation was not. In the second year after lime was applied there was a close correlation between crop yield, number of bacteria, and amount of nitrification.

That nitrifying organisms can withstand large quantities of alkali was shown in investigations at the California station, but strains differ in this respect. Nitrogen-fixing organisms did not function well except in a slightly acid medium.

The Utah station found that more water is required for optimum bacterial activity in alkali soil than in those free from excess of alkali. In very dilute solutions, nitrates in the soil solution stimulated nitrogen fixation, but in larger quantities retarded it. Likewise very small quantities of dried blood accelerated the action, but larger quantities (2 per cent) inhibited fixation. Barnyard manure up to 15 tons per acre accelerated fixation. The presence of arsenites in soil, as may result from spraying, was found to reduce the action of beneficial bacteria, such as ammonifiers.

Increasing the pH value of an alkali soil to 6, or lowering that of an acid soil was shown by the Kansas station to make conditions favorable for the growth of Azotobacter. By adding organic acid to a soil, the nitrogen ion concentration was lowered. Acetic acid up to the rate of 45 tons per acre disappeared when added to the soil, the organisms using the acid as a source of food.

Sodium chloride and sulfate reduced ammonification and nitrification in experiments at the Idaho station, but sodium carbonate slightly increased these processes and also showed a slight tendency to overcome the toxicity of the chloride and sulfate.

Organic matter.—The Pennsylvania station found that land kept in permanent sod for 40 years maintained the organic matter of the soil better than a rotation system, even when manure was applied. With continuous cropping manure-treated soils lost 85 per cent of the organic matter applied, but there was more residual organic matter in the soil that had received lime with the manure. The heavier the manure application the greater was the relative loss of applied organic matter. Manured plats had increased in organic matter at the rate of 343 pounds per acre. Nitrate of soda and sulfate of ammonia plats contained less organic matter than those receiving potash and phosphate. Manured plats contained 2,000 pounds per acre more active humus than complete fertilizer plats. There was less residual active humus in the plats receiving land plaster, burnt lime, limestone, nitrogen, or potash than in the check plats. An average of 63 per cent of the total nitrogen applied in manure and 74 per cent of that applied in mineral fertilizers had been lost from the soil. Land plaster plats contained considerably less organic matter than plats treated with burnt lime and limestone. The results, therefore, show no justification for the theory that burnt lime exerts a more destructive action on the organic matter of the soil than other forms.

After 10 years' treatment limed plats at the New York Cornell station contained more organic carbon and nitrogen than unlimed plats. There had been a decrease in organic carbon and nitrogen on the plats in rotation without legumes. Plats kept in grass showed an increase in organic carbon and nitrogen, and plats in rotation with legumes contain more nitrogen than those in rotation without legumes, the increase being greater in the limed than in the unlimed soil. Crops in rotation with legumes removed more nitrogen from the soil than did those without legumes. Plats kept in grass lost less nitrogen in the crops than did the plats in rotation with legumes. The ratio of organic carbon to nitrogen remained fairly constant under various treatments, decreasing or increasing correspondingly.

The Washington station found that straw with a nitrogen content of about 0.5 per cent decomposed at a very uniform rate throughout the growing season and that alfalfa, with a nitrogen content of about 2.5 per cent, decomposed very rapidly during the initial period of about 16 days and then dropped below straw. Thus the soil organic matter accumulates more rapidly with alfalfa than with straw. From the standpoint of crop yield, straw acted detrimentally by inhibiting nitrate accumulation, but alfalfa rapidly increased the nitrate-nitrogen content. The biological activity of soils decreased directly with the loss of organic matter and nitrogen. The nitrogen-carbon ratio in soils tends to become practically constant at about 1 : 12, irrespective of the source or proportions of these constituents applied. The carbon can not be permanently increased or even maintained unless the necessary nitrogen is provided to maintain the ratio. The nitrogen-carbon ratio in material applied to the soil had a pronounced influence on the kind and rate of decomposition. Thus wheat straw with a wide nitrogen-carbon ratio (1 : 75) had a depressing effect on nitrate formation when applied to the soil, which persisted until decomposition had proceeded to the point of restoring the proper ratio, whereas legume hay or green manure with a nitrogen-carbon ratio of 1 : 10 gave an immediate and rapid formation of nitrates. Studies on dry basaltic soils, under a limited rainfall, with a low clay content, showed that while the nitrogen content of the soil increased with precipitation the nitrogen-carbon ratio remained constant, being narrower in the subsoil than in the surface soil. The organic matter of the subsoil was but slightly affected by precipitation. When precipitation exceeded 15 inches there was considerable loss of nitrogen. It is suggested that this loss can be prevented by replacing summer fallow with a rotation containing legumes.

Solubility of soil constituents.—The Iowa station found no relation to exist between total and organic phosphate in the soil or between carbon dioxide

formation and soluble potash, there being various factors which affect the solubility of potash.

Continued treatment with acid phosphate depleted available potash, whereas calcium sulfate and sodium nitrate increased the water-soluble potash, in experiments at the Ohio station. Limed soils showed a higher potash-fixing power than unlimed soils.

In lysimeter studies the Florida station found that soils receiving their nitrogen in organic form, as from manure, lost less nitrogen and other constituents in the drainage water than those receiving nitrogen in mineral form. Applications of ammonium sulfate caused increased losses of lime, potash, and aluminum.

All forms of calcium and magnesium other than sulfates caused a depression rather than an increase in the amount of potash leached from a soil, in experiments at the Tennessee station. Similar results were obtained by the New York Cornell station, which found that lime made potash less soluble, as shown by the drainage water.

Soils normally showing no water-soluble potash contained soluble potash after treatment with sulfur at rates of 500 to 1,000 pounds per acre, in experiments at the Kentucky station. In only one case was it present after treatment with gypsum.

The Illinois station observed that when rock phosphate and acid phosphate were added to soil they quickly became relatively insoluble, the reaction being practically completed in 24 hours, after which there was no significant difference in the amount extracted from the two carriers. Soils varied widely in their ability to absorb phosphorus from applied phosphates and in the effect of different chemical compounds upon the amount of phosphorus which could be extracted. Double phosphates of iron and alumina and possibly silica were the compounds concerned in the fixation process. With a soil composed wholly of silica, recovery of phosphorus was 60 per cent or more if iron or aluminum was added alone, but if both were added together recovery fell to 30 per cent.

Sulfur.—Soils high in organic matter were found by the Illinois station to contain more sulfur than those low in this constituent. Determinations of sulfur in the rainfall showed that from 30 to 50 pounds per acre are added from this source during the season, which is in excess of that removed by the crop. The Tennessee station found that the outgo of sulfates was increased by the addition of any form of lime and magnesium, except freshly burnt lime, the outgo being decreased with increased applications of the latter. Where excessive quantities of lime were added, the amount of sulfates recovered was less than that brought down by rainfall.

Colloids.—The colloidal swelling of soils was tested by the Arizona station by drying the sample, compressing at 30,000 pounds, adding water or a salt solution, and measuring the expansion. Swelling was accelerated by soluble mineral salts. The temperature of the water affected the rate of swelling, heat accelerating it. Salt or any electrolyte except sulphates also accelerated swelling. Each soil type tested showed a rather characteristic swelling curve at a constant temperature. With the same soil, increasing the viscosity by adding gelatin increased the swelling up to 1 per cent and then retarded it, and adding an electrolyte to the gelatin restored the normal. Apparently the swelling was not due to the viscosity, but the gelatin had a specific effect upon the colloids. This effect is, however, not constant in different soils, suggesting the presence of different colloids.

FERTILIZERS

Standard fertilizers.—Through the efforts of the Texas station, an agreement has been reached among agronomists, chemists, and fertilizer manufacturers on 11 standard fertilizer formulas of high grade for Texas, Louisiana, Arkansas, and possibly Oklahoma. This is in line with similar agreements which have been reached in many of the other fertilizer-using States.

Phosphates.—At the Pennsylvania station, acid phosphate when used without manure was much more effective than rock phosphate, but used with manure the difference was less marked. Sulfur applied with rock phosphate increased its availability.

In experiments extending over 10 years, rock phosphate has shown little effect in the early years of its use at the Virginia station, but is beginning to give very good results which are accentuated by liming.

Ordinary ground rock phosphate, 25 per cent of which is of the fineness of clay, was 49 per cent as effective as acid phosphate, in experiments at the Indiana station. When the phosphate was reground so that 75 per cent of it was as fine as clay, it was 56 per cent as effective as acid phosphate.

Lime.—A comparison of magnesium and nonmagnesium limestone, at the New Jersey stations, showed a slight difference in favor of the former and some evidence that this form favors nitrogen fixation more than nonmagnesium limestone. The results indicated that it is not necessary to fully satisfy the lime requirements of a soil to get good results with most farm crops.

The Rhode Island station has found that with sufficient phosphoric acid there is a marked reduction in the needs for lime.

Gypsum applied as top dressing on new seedings showed no beneficial effects in case of clover or other crops at the Wisconsin station, but at the Oregon station it was found to be especially effective in securing a stand of clover.

Sulfur.—At the Washington sation applications of sulfur on alfalfa at first increased the yield, but this was not maintained without renewed applications. Sulfur applications increased the nitrogen content of the first cutting of clover and alfalfa, but not of the second and third cuttings. The sulfur content of the first cutting of alfalfa was increased, but there was little effect on the percentage of total ash or of calcium. The effects of sulfur varied with different soils, crops, and forms of sulfur. Certain soils showed comparatively little effect of such applications on the soil processes. Additions of organic matter, such as manure, apparently had less effect than did moisture on the behavior of sulfur.

At the Oregon station legumes, particularly alfalfa and red and alsike clover, gave marked response to sulfur fertilizers, which were found to increase the protein content of the crops. Elemental commercial ground sulfur was found to be the most economical form to use, and applications of 100 pounds per acre per year have given marked increase in the yield of crops.

The use of 500 pounds of sulfur per acre on sugar beets, in experiments at the Colorado station, gave an increase in sugar content of 0.5 per cent and increased both purity and tonnage.

At the Idaho station there was greater response to sulfur and less to phosphoric acid in arid than in humid soils. Sulfur increased the nitrogen content of alfalfa, and gypsum increased the yield on Palouse soil.

The use of sulfur slightly decreased the yield of cotton, in experiments at the Texas station, but had no appreciable influence on the development and control of root rot of cotton.

Manure.—Acid phosphate used at the rate of 5 per cent proved to be an efficient preservative of nitrogen in manure, in tests at the New York State station, by inhibiting the organisms that break down the manure. The effect of fresh straw was very detrimental, possibly due to a toxin.

In experiments at the Missouri station manure in a flat pile 6 inches deep lost 39.5 per cent of nitrogen during five months' exposure, from April to September. The loss in a conical pile was 26.55 per cent during the same period. Most of the loss was in a gaseous form.

BACTERIOLOGY

Azotobacter was shown by the Ohio station to grow in an atmosphere of hydrogen, if supplied with nitrogen, showing that the organism is not necessarily an air-nitrogen fixer. In the soil it apparently can not compete with other forms in the utilization of soil nitrogen. It can stand anaerobic conditions and can continue active in an atmosphere of hydrogen and oxygen with no nitrogen. It was found that the dry Azotobacter cell contains about 3 per cent of nitrogen.

A sulfur-oxidizing organism, *Thiobacillus thiooxidans*, was isolated and grown in pure cultures at the New Jersey stations. It gets its carbon dioxide from the atmosphere, being incapable of deriving carbon from carbonates or organic matter, but derives its energy from the oxidation of sulfur. It does not occur in soils to which no sulfur has been added. It is much more active than Beyerinck's organism *T. thioparus*, producing 3 to 4 per cent of acidity in sulfur and standing an acidity of pH 0.58.

Bacillus botulinus was found by the Colorado station in 18 widely distributed soils. Cultures of the organism from canned corn withstood three hours' boiling.

Several bacteriophags were isolated by the Massachusetts station from bacillary white diarrhea, but all were weak. Their real nature, whether enzym or ultramicrobe, has not been determined. A protein extracted from an isolated virulent bacteriophag showed phagic action. The phags were found to cause lysis of the pathogenic bacteria.

PLANT PHYSIOLOGY

Nutrition.—At the Wisconsin station, studies on the feeding power of plants showed that this is not due primarily

to the amounts and kinds of acid excreted, but to various factors of external and internal equilibrium in the nutritient solution. Plants with a high capacity for calcium, feed strongly on rock phosphate because soluble phosphate and calcium carbonate are both removed in proper proportion. When only one soluble product is present, as in feldspar, assimilation of potash depends inversely upon the acidity of the plant sap. The more acid the sap, the more readily can the plant, in competition with the acid system of the soil, obtain the calcium and other basic materials needed to regulate the reaction of the plant sap. It was found that nitrates may be stored by the plant until the proper conditions arise for building up into other forms of nitrogen. The presence of nitrates, as such, in a plant did not materially affect the type of growth. Conditions resulting in a decrease of insoluble nitrogen and a still greater proportional decrease in carbohydrates resulted in a relatively high proportion of insoluble nitrogen to carbohydrates, producing a strongly vegetative and unfruitful plant. Conditions favoring the formation of an abundance of insoluble nitrogen and at the same time an abundance of carbohydrates, resulted in a vigorously vegetative and fruitful plant. Conditions resulting in a decrease of available soluble nitrogen without a decrease in carbohydrates caused a very high proportion of carbohydrates to insoluble nitrogen and produced a weakly vegetable and unfruitful plant. In the case of tomatoes, light within the limits of a six-hour day did not markedly limit the building up of nitrates to insoluble forms of nitrogen, provided there was present an available supply of carbohydrates. A large decrease of carbohydrates in the tomato plant, already high in carbohydrates, was apparently coupled with decomposition of insoluble nitrogen. When this decrease was brought about by reduction in time of exposure to light, new growth was produced, even though there was no external supply of nitrates available to the plant.

With tomatoes grown in a fertile soil and transplanted to sand with a nutrient solution in which different elements were omitted, the following results were obtained by the New Hampshire station: With no phosphorus, the plants were feebly vegetative, deep green in color, and nonfruitful. Compared with those grown with a complete nutrient solution, they were higher in total nitrogen, nitrate nitrogen, and chlorophyll content and also higher in free reducing sugars and total carbohydrates. With no nitrogen, the plants were feebly vegetative and nonfruitful but had a pale green color, and compared with complete nutrient solution plants, were lower in total nitrogen, nitrate nitrogen, and chlorophyll content and higher in free reducing sugars and total carbohydrates. With no sulfur, they were only slightly less vegetative and fruitful than those grown in complete solutions and were slightly higher in total nitrogen, free reducing sugars and carbohydrates, but the effect of omitting the sulfur was not marked. A study of the nitrogen distribution showed that those plants grown in the nutrient solution minus phosphorus were much lower in insoluble nitrogen, higher in soluble nitrogen, and slightly higher in lipoid nitrogen. With nutrient solutions containing no nitrogen, the plants were high in total nitrogen and nitrate nitrogen; with no phosphorus, they were low in total nitrogen. Plants grown without phosphorus, although high in total and nitrate nitrogen, were low in synthesized or protein nitrogen, those grown without nitrogen also being low in protein nitrogen. Large applications of available phosphorus increased fruitfulness and hastened maturity with tomatoes.

Studies with the peach, at the Delaware station, showed that the rapidity of starch transformation was much increased by nitrogenous fertilizers.

At the New York Cornell station, it was found to take about two weeks for nutrients to go from the root to the top of a tree. Nitrates seemed to increase the rate of movement. If nutrients were fed to roots on one side of a tree, they stayed on that side, but water was translocated to all parts of the tree. Similar results were obtained at the Maryland station, where fertilizers applied to the roots on one side of a tree were found to be used only by the trunk, limbs, and leaves directly above and were not diffused throughout the tree.

Nitrates penetrate the cell much more rapidly from slightly acid than from slightly alkaline soils, according to experiments at the California station, the indications being that alkalinity is undesirable in a soil solution. The concentration of ions in cell sap was much higher than in the soil solution, the sap being more acid than the soil solution.

Alfalfa grown in solutions containing sodium chloride, at the New Jersey stations, gave higher yields than

plants grown with no sodium chloride, the roots showing a greater relative increase than the tops. The chlorine content of the plant increased with increasing supply of the element, the greater part being in the tops. With plants grown in solutions lacking the essential elements, the most striking injurious effects were observed in plants in solutions lacking lime, potash, and nitrogen, those lacking phosphorus and iron suffering least. It appeared that sodium could fully replace potassium as a plant nutrient up to the blossoming stage. The calcium content of the plant was greatly increased when potassium and nitrogen were lacking and slightly increased in the absence of phosphorus. The amount of magnesium in the plant was increased when sulphur was omitted and where potassium was replaced by sodium, whereas a decrease of 90 per cent occurred in the absence of nitrogen. Considerably less nitrogen was absorbed by the plant in the absence of calcium and potassium, but the elimination of sulfur and iron caused an increase in nitrogen absorption. Plants in solutions in which potassium was replaced by ammonium sulfate contained more nitrogen. When the solutions were aerated there was superior root growth, reflected in accelerated growth of tops during the later stages of development.

Metabolism.—Studies at the Wisconsin station indicated that, in general, climatic effects on plant metabolism are more pronounced than are those of nutrients. Increase of polysaccharids was found to be associated with a decrease of temperature, with red clover and buckwheat.

Evidence that one of the unicellular green algae (*Chlorella* sp.) can synthesize protein in total darkness, when nitrogen is supplied in inorganic combination, was secured by the New York Cornell station.

Respiration showed little effect on the protein percentage in wheat, oats, and barley, in studies at the Minnesota station. The Pennsylvania station found that nitrates decreased from the lower part of the plant upward, but some was found in the leaves and upper parts.

The New York Cornell station found a relatively high catalase activity in leaves from apple trees growing in good soil, from those receiving clean cultivation, or from heavily pruned or nitrogen-fertilized trees in sod. On the other hand, the activity was relatively low in leaves from trees growing in poor, sandy, or noncultivated land, receiving no fertilizer, and from trees that had been ringed or otherwise injured in such a way as to reduce vegetative activity. It is believed that a test of this activity will serve as a rather sensitive indicator of the nutritive condition. A relatively low catalase activity accompanied a nutritive condition in which the proportion of nitrogen to carbohydrates was very low; and the higher the proportion, the greater was the catalase activity.

Enzymic activity in the peach has been studied extensively at the Delaware station. Nitrogen was found to increase the diastatic activity, and this affected the quality of the fruit. With large applications of nitrogen, tannin transformation was slow and there was an accumulation of this substance in the fruit, which thus became bitter. Moderate quantities of nitrogen were found to increase the enzymatic activity in the transformation of amygdalin, but larger quantities did not. Although the yields were better from nitrogenous fertilization, the quality of the fruit suffered. Phosphates were found to increase the amygdalin. Increased nitrogen application did not increase the protein enzymic action and transformation. In studies with corn it was found that high protein was associated with high reducing enzymes, and a high oil content with high diastatic activity. Using this as a basis in inbreeding corn, vigor has been kept up with high protein and oil strains but not with low strains. An increase in vigor did not necessarily mean an increase in yield.

A study of the nature of the hydathode water of plants, at the New York Cornell station, showed it to contain substances similar to that of the plant sap and possibly similar to the secretions from the plant roots. The total solids in hydathode water from the corn plant was 1,030 parts per million. In timothy it was considerably less. These solids were more than half organic. There were indications of the presence of nitrites, nitrates, materials capable of reducing methylene blue, catalases, and peroxidases. It was a good medium for the growth of bacteria. The hydathode water obtained from young plants of corn, timothy, and oats was nearly neutral, but the acidity increased as the plants got older.

Growth.—In studies at the New York Cornell station the top growth of barley and corn was nearly always increased as the supply of nitrogen increased. The absolute root growth, on

the other hand, was usually decreased with high nitrate concentration in the nutrient solution. With medium nitrate concentration the total growth was sometimes greater and sometimes less than with low concentration. The ratio of top to root always increased as the nitrate concentration increased, often resulting with corn and barley, in actually smaller roots. Flax showed no consistent response to changes in nitrate concentration. As the corn and barley plants grew older, the smaller were the roots relative to the tops. Nitrates did not, however, directly decrease root growth. With a low water content of the soil, longer roots were produced; and nitrates produced smaller roots in relation to the top growth unless the tops were removed, in which case the roots were stunted.

Potatoes showed an increase in dry weight of tops with each increase in soil moisture, with both high and low fertilizer treatment, in experiments at the New Jersey stations; but less water was required to produce a gain of dry tops in the high fertilizer series than in the low. Maximum yields of tubers were produced with a medium moisture content. The differences in yield between cultures of different moisture content were greater than between cultures of the same moisture content but with different fertilizer treatment.

Transpiration and leaf temperature.—An investigation of the effect of transpiration on temperature, at the New York Cornell station, showed that this does not cool the leaf much and does not have an effect in regulating the temperature. At the Kansas station, observations taken between 9 a. m. and 4 p. m., on wilted leaves of corn, sorghum, soy beans, and cowpeas showed the temperature to be respectively 1.85°, 1.55°, 2.8°, and 4.65° C. higher than the temperature of turgid leaves of these plants under the same conditions, with the exception of the moisture content of the soil. The percentage of available water in the soil, above the wilting coefficient, was from 2 to 4 per cent for the wilted plants and from 10 to 12 per cent for the turgid plants. The ratio of the rate of transpiration of the turgid leaves to that of the wilted leaves was 2.4 to 1 in the case of corn and sorghum and 3.5 to 1 in the case of cowpeas and soybeans. The temperature of the leaves during the night was approximately that of the air. During the hours of early morning and evening and during the day when weather conditions were comparatively mild, the temperature of a turgid leaf was slightly lower than that of the air. In direct sunlight, the temperature of the turgid leaves fluctuated slightly above or below air temperature, but the average temperature of the leaves was approximately that of the air. The temperature of the base of the leaves in direct sunlight was always lower than that of the tip region, varying from 1° to 1.5° C. depending upon the nature of the leaf and the available water supply. The temperature of sprayed leaves of potatoes was lower than unsprayed leaves.

Effect of light.—At the Massachusetts station a reduction of 15 per cent of light gave a marked increase in vegetative growth. A 20 per cent shading delayed maturity of the potato. Studies on ultra-violet light in the greenhouse indicated that it produces a kind of coagulation. When the short light waves were cut out by suitable glasses there was greater growth of the plant and their presence produced a more compact habit of growth. Insects were found to be able to distinguish ultra-violet light and will go to it. Red light produced most photosynthesis, and the use of red light in the night increased growth perceptibly.

In investigations at the New Hampshire station with an abundant supply of moisture and nitrogen, with a short day, plants were light green, nonfruitful, low in carbohydrates, and high in total and nitrate nitrogen. With a long day they were green in color but unfruitful, low in carbohydrates, and high in total and nitrate nitrogen. With available nitrogen restricted in proportion to daylight, they were green, fruitful, and medium in carbohydrates and in total and nitrate nitrogen, and with much restricted nitrogen and full daylight they were yellowish green in color, unfruitful, high in carbohydrates, and low in total nitrogen, with an abundance of nitrate nitrogen. Shading apple trees reduced fruit-bud formation to almost zero, while unshaded trees gave about 65 per cent of fruit-bud formation. The shaded trees were higher in moisture and total nitrogen and lower in dry matter, free reducing sugars, and starch. Shading appeared to be effective either by reducing carbon elimination or by increasing nitrogen intake or both. Ringing, on the other hand, greatly increased fruit-bud formation, apparently by preventing translocation of the carbohydrates to the roots. Shaded trees were much lower in carbohydrates, but were not

lower and were perhaps even higher, in insoluble nitrogen. Shading did not affect protein synthesis.

Sunlight gave a high nitrogen–low carbon ratio, in experiments at the Ohio station. With a number of plants light increased the leaf surface but not the root system, and the leaves were thinner.

When too little light was supplied, the Michigan station found that wheat plants were abnormally tall. With increased light they were normal, but the same combination of salts (in triangle tests) was not the optimum for both conditions, showing that light is a factor in the utilization of nutrients. Too strong light killed the plants.

Effect of manganese, iron, and aluminum.—In experiments at the Kentucky station with a number of kinds of plants grown with and without manganese, all plants from which this was withheld showed conspicuous signs of the need of this element, as indicated by stunted growth, lack of chlorophyll, and dying back of the young shoots, and finally of the whole plant, without fructification. It seemed to be a necessary element for the growth of the plants. In cereal seeds tested the manganese content was equal to the iron content, but in legume seeds it was less. In addition to manganese, copper and zinc in minute quantities were also shown to be necessary for plant growth. All three of these elements were found in the germ of corn, but little or no copper in the endosperm. A little more copper and zinc were found in yellow than in white corn germs.

At the New Jersey stations, quantitative determinations of iron in the plant as a whole showed that a concentration of iron in the nutrient solution in excess of that required to maintain the plant may result in iron toxicity, but the leaves may sometimes become chlorotic from an insufficient supply of iron, with an abundance in the stems and petioles. A concentration in the nutrient solution not above the maximum required to maintain the plant, tended toward an equal distribution throughout the plant. There appeared to be a delicate balance within the plant in regard to this element, which requires that the available iron in the culture medium be limited to very narrow ranges of concentration. Soluble ferric phosphate in low concentrations was toxic to soybeans in solutions containing ammonium sulphate, but ferric glycero-phosphate in the same concentrations, owing to lower solubility, produced excellent plants. The amount of iron required to maintain plants in a healthy condition, when supplied by the latter compound, became very toxic when supplied by the former. A direct correlation was found between the decrease in hydrogen-ion concentration of the culture solution and the appearance of chlorosis in the plant. With soluble aluminum salts, including the nitrate, chloride, and sulfate, low concentrations had little if any effect on the growth of tops of wheat seedlings, but all concentrations were injurious to the growth of the roots, and a progressive decrease in tops and roots took place with increasing concentrations. The toxic effect was the result of the aluminum ion and not the increased hydrogen-ion concentration resulting from hydrolysis.

In a study of the relation of metallic ions to disease, at the Indiana station, corn plants in soil pot cultures were much less affected by innoculations of *Gibberella saubinetii* when aluminum phosphate, ferric phosphate, and manganese phosphate were added than when aluminum sulfate, iron sulfate, and sulfuric acid were added, showing an important relation between the phosphate and metallic ions, in so far as their absorption and use by the plant is concerned.

Seed studies.—The New Jersey stations found that seeds of high medium weight produced better plants than lighter or abnormally heavy seeds. Germination in general took place more rapidly in light than in heavy seeds. In the Lima bean, the average air-dry weight of beans produced was about 44 per cent of the air-dry weight of the tops, hence the average large plants produce a correspondingly greater crop weight. In corn, the air-dry weight of stalk and husk increased with the increase in weight of seed from which the plant was grown.

Some seeds withstood a pressure of 40,000 pounds to the square inch, alfalfa as high as 60,000 pounds, without destroying germination ability, in tests at the West Virginia station. As organisms withstand as high a pressure, and spore-forming organisms even higher, the method seems to have no value for treating seeds for disease control.

Weed seeds buried 4 feet in the ground, at the Iowa station, showed vitality after the following lengths of time: Velvet weed, jimson weed, and horse nettle, 11 years; five finger, 10 years; curled dock and coffee tree, 9 years; tumbling pig-weed, 8 years;

burdock and catnip, 7 years; lambs quarters, 6 years; and field thistle, quack grass, dalea, evening primrose, and green foxtail, 5 years.

Vitamins for plant growth.—Studies of the bios requirement of baker's yeast, at the Minnesota station, showed that normal growth is impossible without something that appears to be of the nature of a vitamin but not identical with any of the known vitamins.

GENETICS

Inheritance in beans.—Crosses of a large-eyed bean and a small white bean, at the Maine station, showed large size to be associated with color, pattern, and pigmentation factors of the larger parent.

Inheritance of pericarp color.—Studies at the New York Cornell station, mainly with corn, showed pericarp color to be inherited in a strictly Mendelian way in some cases; and where it is not it may be due to the color being in the epidermis, which is not inherited.

Inheritance of nakedness in cotton.—Results obtained at the North Carolina station indicated that nakedness of cottonseed is a simple dominant character, in strains isolated from King; and it is believed it will be possible to produce upland varieties with naked seeds.

Color inheritance in sorghums.—At the Texas station, intravarietal crosses with yellow and white seed-coat colors, in milo, showed the yellow color to be completely dominant; in the case of red and white kafirs there was a blending of colors but no indication of hybrid vigor of growth, indicating that the different kafirs and milos are closely related.

Inheritance in cereals.—The Minnesota station finds that rust resistance in cereals is inherited as a single genetic factor. No correlation was found between inheritance of growth habit and reaction to rust.

Studies of wheat, at the Maine station, showed that in the einkorn group (*Triticum monococcum*) there are 7 pairs of chromosomes, in the emmer group 14 pairs, and in the vulgare group 21 pairs. Attempts are being made to combine the disease and drought resistance of the durum or emmer group with the bread-making qualities of the vulgare group by crossing the 14 and 21 chromosome groups. All of the intermediate hybrids from the cross are sterile, but all with 14 and 21 chromosomes are fertile, with good bread properties. All of the hybrids with an intermediate number of chromosomes either die or are sterile. The wild variety, with 7 chromosomes, is of no value. The 14-chromosome variety is adapted only to arid regions and is not very adaptable to other conditions. The 21-chromosome group is the most useful and widely grown; but although it is most variable and adapted to a wider range of conditions, it is not always the highest yielder. The members of the einkorn and emmer groups are found mostly in the regions where wheat originated. Certain varieties of *T. turgidum* of the 14-chromosome or emmer group are the most productive of all wheats. The size of the pollen grain is closely correlated with the chromosome numbers in the various species of wheat. In all crosses the F_1 plants are unusually vigorous and sterility is not due to poor vegetative development, but is caused by the formation of nonfunctional gametes.

Wheat-rye crosses, at the Georgia station, produced a progeny that was almost sterile.

Inheritance in phlox.—Large-eyed (*orbicularis*) phlox plants were found by the Pennsylvania station to be monohybrids, exhibiting segregation on self-pollination, into families that are one-half orbiculous, one-quarter small-eyed, and one-quarter astylis, the latter being a defective type. The character of singleness in flowers was sometimes completely dominant and at other times nearly recessive.

Inheritance of color in dairy cattle.—Crosses of Guernseys and Holsteins, made at the Illinois station, showed that in the F_2 generation red and black are all dimorphic, black being dominant to red, and segregation occurs in a 1:2:1 ratio. In 126 reciprocal matings of purebred Holstein and Guernsey parents, 119 black and white and 7 red and white offspring were produced.

Inheritance of plumage color in fowls.—At the Connecticut Storrs station plumage color was found to be sex linked and transmitted from mother to son. In barred feathers the rhythm may be due to one factor and the color to another, these being sex linked. It is believed possible that egg production may be tied up with a color factor.

Inheritance of broodiness.—The Massachusetts station found that there is apparently no sex-linkage broodiness and that the character is transmitted by both parents.

FIELD CROPS

Cereals.—Studies on corn at the Nebraska station indicate that an in

crease in kernel weight due to fertilization by foreign pollen may result either from heterosis or from a change in the type of endosperm. The increase from heterosis was marked in the case of selfed strains; but commercial varieties of corn, being heterozygous, responded relatively little to the immediate effect of foreign pollen. Studies at the Connecticut State station on the principles of inbreeding showed that it is as essential to control heredity through the pollen parent as through the seed parent. The loss of vigor in the F_1 generation was from 50 to 100 per cent, the line usually becoming extinct in three or four generations.

After 26 generations of selection for special characters, at the Ilinois station, high protein strains averaged 17.33 per cent protein, low protein strains 7.41 per cent, high oil strains 9.86 per cent oil, and low oil strains 1.67 per cent. The high and low ear strains averaged 105.3 inches and 13.1 inches, respectively, in height of ear.

The phytosterols of corn oil and corn pollen were found by the New York State station to be different from those of other plants. The alcohol-ether extract of corn germ contained at least two phytosterols, one inactive, the other levorotary.

Fertilizer experiments with corn at the Georgia station showed that top dressing with sodium nitrate when the plants were about 2½ feet high gave better results than later applications. Marked effects resulted from the use of phosphates on corn at the Vermont station. Two applications were better than one, the second when the plant was in flower. Broadcasting commercial fertilizers ahead of the planter has given the best results in eight years' experiments at the Missouri station.

The New York State station found the popping quality of pop corn to depend upon variety, moisture content, and temperature of the popper. Varieties with small flinty kernels pop best, Japan Rice being one of the very best, its volume increasing from 28 to 31 times. Pop corn readily becomes too dry to pop well. The highest popping yields were obtained with corn having a moisture content of 13.5 to 14.5 per cent.

In studies of the lodging of grain, at the Ohio station, it was observed that with both wheat and oats there was a larger number of culms in the lodged area than in the upright. Thick seeding resulted in thin stem walls and a greater tendency to lodge. In thinner growths on poorer soils there was a higher carbohydrate content than in plants grown on richer soils, and the carbohydrate-nitrogen ratio was wider. Both fertility and method of culture had a marked effect on this ratio. An increase in moisture resulted in more straw and less grain and additions of available nitrogen increased tillering, stooling, and number of plants. Shaded areas, using only one layer of cheesecloth, showed more lodging than unshaded areas, both with wheat and oats. In the shaded area the carbohydrate-nitrogen ratio of the plants was higher than in case of the unshaded areas. The carbohydrates were higher in the unshaded stems, but there was considerable difference in varieties in this respect. Experiments with rye showed that the greater the tillering the weaker the straw. High nitrates in the soil favored lodging. There was more lodging on low ground, and plants from smaller seed showed a greater tendency to lodge. The thicker the stand the greater was the tendency to lodge.

Nitrate did not increase the yield of wheat at the Kentucky station when applied in the fall, and decreased the yield when applied in the spring, stimulating rank growth which made the plants more susceptible to disease. At the Arizona station an application of sodium nitrate on wheat (150 pounds per acre) increased the nitrogen content from 11.49 to 14.45 per cent. Late irrigations did not affect the nitrogen content. Barnyard manure (5 tons per acre) increased the nitrogen content very slightly. The yield was increased by nitrate of soda from 500 to 600 pounds per acre over plats receiving no fertilizer. Tests of time of applying nitrate at the Ohio station showed that the later the application was made in the spring the more protein there was in the grain. Experiments at the Idaho station showed that wheat following legumes increased in yield and in nitrogen content, owing to increased available nitrogen in the soil.

Rate and date tests of seeding winter wheat at the Utah station showed decided advantage in seeding not less than 5 pecks to the acre, and sowings made from September 15 to October 1 gave the highest yields. Wheat seeded in rows and cultivated gave significantly lower yields than like seedings uncultivated. In rate and date tests at the West Virginia station, 8 pecks per acre and seedings from September 20 to 30 gave

the highest yields. At the Montana station winter wheat seeded with the deep furrow drill produced 7 bushels more per acre than that sown with the ordinary drill and showed a survival of 87 per cent in the spring as against 51 per cent for the ordinary drill seeding. North and south seeding gave better yields than east and west seeding at the Kansas station.

The correlation between the calcium content of wheat and the pH value of the soil is usually very high, according to the Kansas station, but depends somewhat on the character of the soil, 0.1 per cent of calcium in a sandy soil having as great an effect as 0.6 per cent in a clay soil. A fairly close correlation between baking quality and water-soluble ash was found by the Nebraska station, the higher baking quality being associated with higher percentages of water-soluble ash. Environmental influences, particularly the weather, are dominant over soil differences in regard to yield, according to the Maryland station.

The awn plays a rather important rôle in the maturation of the wheat kernel, according to the Kansas station, bearded wheat showing a higher average weight of grain per plant and plumper kernels, as well as a higher yield.

The California station has succeeded in overcoming the foul condition which occurs in rice fields after three of four years of irrigating, by submerging the land after seeding to rice. Results obtained at the Louisiana station emphasize the advantage of rotating rice with an occasional crop of soy beans.

Potatoes.—Pure line selection with potatoes at the Montana station has shown that there are many distinct strains within varieties which differ materially as to yields, rate at which they run out, and resistance to disease, and indicates the need of systematic roguing or improvement work in order to keep varieties from deteriorating. Hill selection as compared with unselected strains, tried out on six different farms by the New York Cornell station, gave an average increase of 48 bushels per acre.

Relatively low temperatures during August and September are apparently one of the most important factors in producing good seed, according to the Nebraska station. Mulching was found to aid in maintaining the desired temperature. For best results the temperature of the growing season, from June 1 to September 30, should average below 67° F. Conditions in July and August are of special importance in connection with the late potato crop. Better seed was produced in dry-land areas than in irrigated regions. The West Virginia station found the practice of rubbing the sprouts off of seed potatoes to be disadvantageous. A study of place effect, in cooperation with the Minnesota station, in the production of potato seed stock, indicated no difference in yielding ability. At the New Hampshire station the yield from home-grown seed was 1.9 times less than that from the same strain grown in Maine.

Irrigated and nonirrigated seed potatoes showed comparatively little difference in value, in experiments at the Montana station, either on irrigated or dry land, provided the stock was equally free from disease. The most practical farm method for improvement was to pick out the best-looking plants in a field and from these in turn select and use the heavier yielding hills. Potato seed cut and planted the same day gave decidedly better results than did seed which had been cut some time previous to the day of planting. Cutting the seed 2 days before planting decreased the yield 60 per cent, and cutting 18 days before planting, 98 per cent. Second-crop immature seed gave better yields than matured stock, and cold-storage seed yielded much heavier than that from ordinary storage.

Treatment by submersion of the tubers, even after they had begun to sprout, in a solution of corrosive sublimate, 4 ounces to 30 gallons of water, for a half hour did not affect the stand at the New Hampshire station, and the use of salt with the solution was harmless.

In fertilizer tests at the New Jersey stations practically the same results were obtained from plats receiving all nitrogen in inorganic form as from those receiving half inorganic and half organic nitrogen. Five per cent of potash gave the maximum increase of yield. Fertilizer in direct contact with the seed reduced the crop 50 per cent if there was not much rain. The New Hampshire station found that liming potato land gave very unsatisfactory results, the potatoes on limed soils being 100 per cent scabby.

The deterioration of potatoes under irrigation, as compared with dry-land culture, was found by the Nebraska station to be largely due to one or more of the so-called virus diseases, the trouble being more pronounced

under irrigation than under dry-land culture.

Cotton.—A comparison at the Oklahoma station of the same seed on lowland and upland gave a staple one-eighth to one-fourth inch longer on lowland. In studies on the density of fiber growth on the seed coat, the North Carolina station found density to be closely correlated with weak tensile strength and soft textures.

Cotton planted at various rates and thinned when 2 to 4 inches high and also when 6 to 12 inches high gave a decrease in every case when thinned late at the Georgia station. At the Texas station medium-thick planting 6 to 18 inches in the row gave the highest yields. Deferred thinning decreased the yield as compared with thinning at the usual time. The Arizona station found that time and method of irrigation had more influence on maturity than methods of thinning. Topping in the middle of July apparently paid, but not when done the middle of August or later. The fuzz on upland cottonseed was found to retard the absorption of moisture; therefore, in order to get a good stand, it was necessary to plant such cotton deeper than the smooth-seeded kinds.

In experiments on the time of applying sodium nitrate, the Alabama station obtained the best results when one-fourth of the nitrate was drilled in the row at the time of planting and the remainder applied at the time of the first cultivation after chopping out.

Cotton on uncultivated plats matured early, and thus escaped boll-weevil injury to a considerable extent, in experiments at the North Carolina station. Growth ceased almost as soon as cultivation stopped. As wide variation was observed in oil content of the seed of the same variety on different plats as between varieties. Fertilizers did not seem to influence the oil content.

Tobacco.—Round Tip, a variety of tobacco originated by the Connecticut State station four years ago, a cross between Broadleaf and Sumatra and now extensively grown in the State and also in Florida, Porto Rico, and Venezuela, has been found to stand up well in the field, to be resistant to root rot, and true to type. Crossing of high-producing strains at the Pennsylvania station has resulted in several excellent types, among which are Hibshman Seedleaf, now extensively grown, Ramm Havana, which is very promising, and a more recent variety, Olson Seedleaf, which is attracting attention.

Tobacco grown after orchard grass at the Kentucky station, in a 4-year rotation of wheat, clover and orchard grass, orchard grass, and tobacco, gave considerably better quality of leaf than when following corn or other crops, and the average yield was better. In a 3-year rotation tobacco after redtop was decidedly better than after wheat or rape.

In experiments at the Pennsylvania station, an application of 1,500 pounds cottonseed meal, 300 pounds acid phosphate, and 200 pounds potassium sulphate gave equally as large yield and a better quality of leaf than heavy applications of manure either alone or supplemented with fertilizer.

Soybeans.—The Iowa station reports that the culture of soybeans is rapidly extending in the State. As an intercrop with corn it gives a large yield of silage material. Hogging down the crop was found to be less profitable than using it for silage. Of the varieties tested, Manchu, Peking, and Midwest have given good results, the latter two especially in the south. They grow well on acid soils. Manchu is best for hogging down and Peking for hay, silage, or sheeping down. Inoculation of the soil from time to time has been found necessary.

Soybeans alone produced higher yields of hay than when grown with millet, sorghum, or Sudan grass in experiments at the West Virginia station. Eight pecks per acre was the rate of seeding giving the highest yield. At the Wisconsin station a mixture of Sudan grass and soybeans yielded 2.4 tons of hay per acre and the digestible protein was 66 per cent greater than that of Sudan-grass hay alone. The mixed hay cured more readily than soybeans alone. It was found that varieties of beans differed in their relative susceptibility to inoculation and that the efficiency of the nitrogen fixation varied with the soil composition and reaction. Different strains of bacteria also varied in their nitrogen-fixing efficiency and in their power of producing nodules on the roots of the plants.

Experiments on the time to cut soybeans to get the best quality of hay, at the Ohio station, showed this to be when the pods are fully formed but before the beans are formed, the total nutrients being then highest. Early harvesting was better for the following wheat crop.

A great increase in interest in soybeans in the State is reported by the Missouri station, about 500,000 acres being planted in corn for hogging down. Soybeans grown in mixture with corn reduced the yield of corn, but their own yield more than made up for this loss.

Sorghums.—Marked increase in the height of F_1 hybrids and of succeeding generations was observed at the Kansas station. Forty-eight F_1 plants had an average height of 104 inches, while the average of the parents was only 65 inches. The decrease in vigor of sorghum crosses in generations following F_1 did not seem to be so rapid as with corn.

Gooseneck and Honey-drip sorghum gaves the largest amounts of silage at the Arizona station, but these varieties are coarse and Sumac sorghum is leafy. Of the nonsaccharine sorghums hegari proved best, giving more fodder than milo but not quite so much grain. Sorghum tended to make the soil stiff and lumpy, percolation tests showing that it took water about five times as long to go through such soil as through corn soil. Oats following hegari were inferior to the crop after cotton. Sorghum appeared to reduce accumulation of nitrates in the soil.

In experiments with kafir at the Oklahoma station, no culture or removal of weeds gave a yield of 12 bushels; scraping the ground to cut off the weeds, 25 bushels; and shallow culture gave but little more, as did deep culture, when it followed rain.

A dwarf feterita has been developed by the Texas station, comparable with dwarf milo. It is early and quick-maturing, which gives it an advantage where grain sorghums grow with difficulty.

Clovers, alfalfa, and other legumes.—At the Tennessee station it was found that American strains of clover were very much more susceptible to clover mildew than foreign strains, but much less susceptible to anthracnose. American strains gave slightly less hay from early cuttings, but the foreign strains were almost completely killed off by anthracnose soon after the first cutting, while the American strains made an abundant late crop of hay and survived the winter in good condition. At the Louisiana station all red clover from seed grown in the United States was badly affected with mildew, but that from foreign countries was only slightly affected. Both the New Hampshire and Indiana stations found the southern European clover to be unsuited to conditions in those States.

All alfalfa seed from high altitudes was found by the Colorado station to have a high hard seed content. This appears to be an hereditary character, but is associated with altitude. Turkestan alfalfa has a low hard seed content. Experiments at the Kansas station brought out the danger to the stand of alfalfa of too early and too frequent cuttings and the fact that delayed cutting does not injure the stand but tends to conserve it. The best practice was found by the Wisconsin station to be two cuttings a year and at as late a stage as possible without allowing the hay to become too coarse. In studies of the duty of water for alfalfa at the New Mexico station, this was found to be 4.67 acre-feet per acre, producing 5.47 tons.

Yellow Canadian Albotrae sweet clover has proved very satisfactory for hay and pasture at the Wisconsin station. Being fine-stemmed, with an abundance of leaves, it is more desirable than the ordinary white-blossomed sweet clover. Yields of from 10 to 12 bushels of seed per acre have been obtained. Sweet clover has proved a profitable pasture and green-manure crop at the Maryland station when grown between two crops of wheat, good pasture beginning when the plants were 8 to 10 inches high. Analysis showed the crop to be high in nitrogen and potash but low in phosphorus.

In tests at the Iowa station, to find legumes that would improve very poor acid soils, satisfactory growth with good nodule formation was secured with Mung beans, velvet beans, cowpeas, soybeans, Dalea, and an early strain of lespedeza

Wind and dust storms were found by the Washington station to be negligible factors in the distribution of legume bacteria. Drying out of soils during long, hot, dry periods of summer killed most legume bacteria in the soil. Seeds well inoculated with vigorous bacteria were found to be practically sterile at the end of six months' storage in a moderately dry place, showing that the inoculation of legume crops by persistence on the seeds from one season to another of viable legume bacteria does not generally occur. At the Illinois station none of 25 kinds of legume bacteria studied would cross-inoculate with soybeans, except possibly some strains of cowpea organisms.

Nodule formation was found by the California station to be correlated with soil temperature. In studies at the New Jersey stations maximum nodulation was secured in absence of fertilizer. Calcium appeared to be absolutely essential to nodulation. The higher the moisture content the greater the nodulation. At the Missouri station inoculated soils, exposed out of doors but protected from contamination, after five years still contained living legume bacteria. This indicates that a soil once well inoculated for soybeans or red clover will not need to be reinoculated if these crops recur in a 4 or 5-year rotation.

A newly distributed Hungarian vetch has been shown by the Oregon station to be exceptionally good for heavy, poorly drained land. Very early strains of Korean lespedeza tested by the Iowa station give promise of great value on poor acid soils for pasture and to prevent soil erosion. They give an unusually heavy, strong root growth and are very drought resistant.

Sugar beets.—Beets planted in September and October at the New Mexico station sent up seed stalks the next spring and produced abundance of seed. The maximum sugar content was reached during the latter part of August or in September. The smaller beets had the higher sugar content.

Sugar cane.—The Louisiana station reports that the benefit to the stubble crop of turning under clover was marked, an increase of 1.8 tons of cane being secured where clover was turned under March 20.

Sunflowers.—The Montana station secured the largest yield of sunflowers (26.12 tons per acre) by planting rows 36 inches apart and plants 4 inches apart. Early plantings produced the largest tonnage.

Silage.—At the Idaho station the composition and feeding value of sunflower silage appeared to be best when the plants were cut at the dough stage or just beyond, with about 80 per cent of moisture. When the plants were allowed to become too mature the silage was unpalatable. When the moisture content was over 80 per cent better silage was obtained by wilting to about that percentage.

There was an average loss of 7.59 per cent of dry matter during the ensiling process, in experiments at the Missouri station, the least loss being 4.01 per cent with fresh green corn and the largest 15.29 per cent with cereal crops. The average loss of protein for all crops was 5.44 per cent. There was an apparent gain of 5.94 per cent in ash. The crude fiber content remained practically unchanged. The nitrogen-free extract showed an average loss of 10.29 per cent. The loss in dry matter and of nitrogen-free extract of corn shocked in the field was approximately twice that in the silo.

Grasses and pastures.—Bahia grass (*Paspalum notatum*) has been tested by the Florida station in nearly every county in the State with good results. Dallis grass (*P. dilatatum*) and Vasey grass (*P. larranagai*) have proved to be the best two year-round wet, heavy land pasture grasses. Centipede grass (*Eremochloa ophiuroides*), a Chinese importation, bids fair to make an excellent lawn and golf course grass. Serradella shows some promise as a winter legume. Hubam clover has given good growth on flatwoods soil but poor on high pine land. As a soiling crop, Napier grass has given higher yields than corn or sorghum. Crotalarias give promise of being valuable green manure and cover crops, especially for orange and pecan groves.

In lawn-grass studies at the Rhode Island station, Rhode Island bent grass and red fescue have been found to possess great tolerance for soils that are so acid that they will not grow weeds, and to make a fine lawn especially for putting greens. Applications of ammonium sulphate bringing the acidity up to pH 4.5 are recommended as a top dressing to produce weedless lawns. It can be applied best in a mixture of 250 pounds each of acid phosphate, muriate of potash, and ammonium sulphate. More than this amount of acid phosphate tends to counteract soil acidity.

More than 300 selections of orchard grass have been made at the Virginia station, showing wide variation in form and earliness. One very promising strain has been isolated and is being increased for distribution.

Harding grass is proving valuable for pasture at the California station, being drought resistant and growing well with the natural rainfall of the State. In pasture fertilizer tests at the Pennsylvania station, grass generally predominated over clovers in high nitrogen plats, white and red clovers being crowded out. Clovers survived best in the struggle for existence on plats receiving a mixture of phosphate and potash with little or no nitrogen. The best growth was on the plats receiving all three elements.

In tests at the New Hampshire station, with the price of fertilizer high and of hay low, the average increase in yield did not pay the cost of fertilizer and the labor of applying it.

In very wet seasons good yields of hay were secured without top dressing. In very dry seasons the effect of the fertilizer was lessened. With an old turf, composed mainly of wild grasses, the increase in yield was not usually appreciable. With a comparatively new sod, in a normal season, with hay and fertilizers at a parity in price, nitrogenous materials, such as sodium nitrate or ammonium sulphate proved profitable.

Rotations.—The Utah station found two years of wheat followed by an intertilled crop to be better than having oats or barley serve as a second cereal crop. Corn after alfalfa showed thriftier growth than after wheat; wheat, on the other hand, often suffered severely after this legume. Alfalfa on dry lands gave best returns when allowed to remain on the same land longer than four or five years. A rotation consisting wholly of annual crops and without manure was very exhausting. A rotation including alfalfa and manure maintained the soil in high productivity. Light applications of manure were of more value than heavy, but 40 tons per acre per year was not excessive for sugar beets and was an effective means of combatting blight (*Phoma betæ*). Sugar beets were more susceptible to blight when following some other crop than sugar beets. A green-manure crop of field peas was not effective in increasing the yield of a succeeding sugar-beet crop.

The Kansas station found that wheat following alfalfa contained 3 to 4 per cent more protein but weighed less per bushel than that following bromegrass. In rotations, shallow plowing seemed as effective as deep and gave as much nitrification.

In eight years' experiments at the Indiana station, wheat following soybeans averaged 31.4 bushels per acre as compared with 24.5 bushels after corn. The least profitable rotation has been corn, oats, clover, yielding $22.68 gross returns per acre per year. The largest returns have been secured from a 6-year rotation of corn, corn, wheat, and three years of alfalfa, which has averaged $34.81 per acre per year.

Potatoes grown in rotation following alfalfa at the Wyoming station produced almost double the yield of those grown on soil that had been continuously in grain, and were less scabby.

Ten years' study, at the Montana station, of the residual effects of crops showed that sugar beets preceded by flax averaged a larger tonnage than when following any other crop. The lowest average yield was secured when beets were preceded by wheat or oats. The average acre yield of corn ranged from 35.1 bushels when following oats to 60.9 bushels when following alfalfa. Yields of wheat were greatest when following beets, averaging 33.2 bushels. The highest average yield of oats was obtained when this crop followed beets.

Residues from sorghums were found by the Arizona station to hinder the growth of wheat, corn, and hegari to a much greater extent than did those from corn. Applications of 40 tons per acre of residues from either corn or sorghums hindered the growth of wheat, as compared with no treatment. Tests at the Rhode Island station show that corn following potatoes or mangels was poor, but following onions or carrots was good.

Weeds.—The Iowa station estimated that the annual loss from weeds in the State is $25,000,000. Tests showed that a mixed culture of weeds and grain transpired more moisture under the same conditions than a grain crop alone. The Kansas station found the prevention of weed growth to be the main factor in preparing for a crop of wheat. Scraping the surface to keep down weeds gave nearly double the yield of no treatment.

HORTICULTURE

Orchard management. — Investigations at the Massachusetts station showed that, in a bearing orchard, sod with applications of sodium nitrate gave the best results; but that, in a growing orchard, cultivation without fertilizers was better. Plats that were mulched had a better appearance and greater leaf area. Those receiving a complete fertilizer were slightly better than those with phosphorus, potash, and lime, with clover. In an old fertilizer-test orchard started many years ago, the unfertilized block is practically of no value while the others are still bearing. In a bearing orchard, limiting the nitrogen supply has resulted in poor color of fruit rather than in affecting productiveness. Fertilizer experiments in a pear orchard indicate that the requirements are the same as for apples, but the effects are not so marked.

In a comparison of orchard plats continuously in sod and those with rye as a cover crop, at the New York Cornell station, nitrates were always low under the sod, except where large quantities had been recently applied and tree growth was greatest in the

sod plats that received the largest amount of nitrate. The removal of moisture from the soil by grass was not an important factor in tree growth, the determining factor being evidently the maintenance of an adequate supply of nitrate nitrogen. The injurious effect of sod on the growth of young apple trees was reduced by the annual application of half a pound of sodium nitrate per tree. Trees in sod plats receiving nitrates showed vigorous terminal growth but few strong branches as compared with trees on cultivated plats. Trees in sod receiving no nitrates had relatively heavy roots as compared with those on cultivated plats, but the roots of trees on sod plats receiving heavy applications of nitrates constituted a much smaller part of the total weight of the tree. The roots of trees in the cultivated plats were more fibrous as compared with those on sod. It is believed that there has been an overemphasis of the importance of cultivation. Timothy evidently hindered the growth of the tree by reducing the available nitrogen. No confirmation has been noted of the toxic action of grass on trees.

After 14 years of orchard treatment at the Delaware station, results show that as long as all three elements are present the proportion does not make much difference. Ten years' results at the Michigan station show that trees growing vigorously are not helped by the use of fertilizers, but poor growing trees can be brought up, especially apple and cherry; and the same applies to strawberries.

Orchard studies at the Illinois station demonstrated that the peach crop may be increased by 158 bushels per acre in soil typical of the peach districts at a cost of $25 per acre for labor, fertilizers, or other equivalent care, and that the application of nitrogenous fertilizers in the apple orchard may increase the crop in a typical apple soil 27 barrels per acre at a cost for labor, fertilizers, or equivalent care of $15 per acre. Fertilization of a commercial orchard showed an increase of 30 barrels per acre as a result of treatment. Applications of nitrate of soda and the use of cowpea cover crops were profitable. Mulching with grass and legumes grown in the orchard between the trees was more profitable than clean cultivation.

Nitrate of soda and straw mulch on straight sod have given marked increases for two years at the Indiana station. Cultivated trees have made the most growth and largest yields.

Nitrogen applied in the fall is stored in the tree, according to the Missouri station, the nitrogen content of the spurs being higher the following spring. Spring applications of nitrogen decreased the starch accumulation in the spurs in June; fall applications increased it in the following June, tending to influence fruit bud formation. Spring applications increased the blossoms, for which reason it is recommended to apply spring applications only in the off year, and fall fertilizers in inverse proportion to the yield of that year in order to overcome an off-year crop. This course has been very successful with York Imperial, a persistent off-year bearer.

Trees in sod at the Pennsylvania station made very large gains from the addition of nitrogenous fertilizers; but trees under cultivation made no response to fertilizers when a good cover crop was grown each year and plowed under in the fall or early spring. Five pounds of nitrate of soda applied to each tree about two weeks before the flower buds break has given as good or better results than 10 pounds applied after blooming is over.

Nitrate of soda applied to blue grass cover crops in orchards increased fruit production at the Iowa station. Winter injury was increased under clean culture.

Apples.—In the pollination of apple orchards, the Maine station found that if honeybees were absent, bumblebees pollinated just as well. There was no evidence that wind was effective in pollinating apples. Commercial varieties of apples grown in Maine are practically self-sterile and must be pollinated with pollen of compatible varieties. Delicious was found to be especially well suited as a pollen variety for McIntosh, Ben Davis, and Baldwin. Wealthy was also found to be especially compatible with McIntosh. Trees of the same age and under the same conditions vary largely in productivity. This is apparently closely associated with a definite type of habit of growth, the productive type of tree being large, open, and spreading, with short laterals and many spurs, while the unproductive type is small and upright, with slender branches and few spurs. Of 881 trees in a Ben Davis orchard, 29 per cent were found to be of the unproductive type, and were kept at an average

loss of 90 cents per tree, while those of the productive type were kept at an average profit of $2.20. The primary causes of differences in productivity in fruit trees may be attributed to soil, root stocks, or differences in cions. Soil played an important part as indicated by the natural grouping together of unproductive trees, and about 35 per cent of these could be attributed to unfavorable root stocks and cions. There was a direct relation between early growth and yield and a correlation between trunk measurement and yield, but the root system was the main factor.

Dropping of fruit early in the growing season was found by the Wisconsin station not to be due to lack of pollination but to nutritional factors. Trees properly pruned and fertilized, so that the bearing top was in good vegetative condition, suffered least from loss of fruit. Noting the period between injury to fruit and dropping with apples, peaches, and plums, the Delaware station found this to grow shorter as the fruit increased in size, being at first 14 days, gradually dropping to 7 or 8 days, and then to 3 or 4 days. It was found that the first wave of drops was of winter buds.

Certain varieties of apples, as Jonathan, Stayman Winesap, Delicious, King David, and Wagener, were observed by the Washington station to ripen on the trees before attaining the desired color; and such factors as color of fruit or seed, size of fruit, or ease with which it breaks from the stem, or combinations of these, could not be used as a safe guide in determining when these varieties should be picked.

The strength of an apple-tree crotch was found by the New York Cornell station to vary directly with the width of the angle between the arms, crotches with equal arms splitting more easily than those with unequal arms. The critical age at which crotches break was just as the tree was coming into bearing.

Experiments in storing apples at the Iowa station indicated that the best way to keep Grimes Golden apples and to avoid scald and internal breakdown was to pick the fruit when fully but not overmatured and to wrap it in an oil covering containing at least 15 per cent of oil by weight. Soft scald was closely associated with maturity.

Peaches.—Breeding work with peaches at the New Jersey stations has resulted in the development and introduction of a white-fleshed variety, the Pioneer, which is earlier than Carman and superior to it in appearance, form, and quality; and the tree is fully as vigorous, hardy, and productive. An early yellow-fleshed variety has also been developed which is equal in quality to the best midseason yellows.

Leguminous cover crops, especially cowpeas, were found by the Illinois station to have an injurious effect on the peach, but this could be corrected by the use of potash. With no cover crop of legumes, nitrogen was the best fertilizing element for both trees and fruit. Fertilization of peach trees with a combination of potash and nitrogen or with stable manure increased the yield over unfertilized plats by 251 bushels per acre.

The importance of thinning peaches early and severely has been emphasized in experiments at the New Jersey stations. The largest and best fruit was produced on trees from which 50 per cent of the fruit had been thinned off early in June. At the West Virginia station, summer pruning of the peach the first fruiting year gave good results, but after that pruning should be light.

In investigations on hardiness of the peach at the Maryland station, the "moisture index," which is the quotient obtained by dividing the moisture content of fruit buds by their dry weight, was found to be low in winter but increased with advance of spring, and appears to be correlated with bud hardiness. Fruit buds were found to depend directly on the roots for their moisture in early autumn, whereas in midwinter the tree was the source.

The peach contains starch and reducing sugar but little if any sucrose in the early stages of development, according to the Delaware station. As the fruit approached maturity, the reducing sugars declined steadily, becoming finally almost constant between 2.25 and 2.75 per cent. The starch content became very low and sucrose increased steadily as the fruit ripened. As the so-called "dead ripe" stage approached, the sucrose content decreased rapidly with a corresponding increase in reducing sugars.

Pears, plums, and prunes.—Bartlett pears differ as to fertility and sterility in different sections and elevations, as brought out by investigations at the California station. In interior valleys they are self-fertile, but above 2,500 feet they are self-sterile. It is found that pears may be retarded in ripening at temperatures above the optimum. The Pineapple pear, a variety highly resistant to fire blight, which the Georgia station has been

testing for 15 years, is attracting much attention.

A pronounced correlation between resistance of the plum to brown rot and crude fiber content was found by the Minnesota station. Varieties containing 6 per cent or more of fiber were comparatively resistant, while with less than this amount, on the dry basis, they were susceptible.

A method of drying prunes with a recirculating air drier devised by the Oregon station has reduced the cost per pound for drying from 2.5 to 1.2 cents and is being widely used.

Cherries.—All varieties of sweet cherries were found by the Oregon station to be self-sterile and Bing, Lambert, and Napoleon to be intersterile. The varieties most suitable for pollination purposes were Republican, Black Tartarian, Centennial, and Governor Wood.

Citrus fruits.—Investigations at the Arizona station on the effect of cover crops on humidity and temperature in citrus orchards in relation to June drought show that the atmospheric temperature was lowered by cover crops 2.5° F. during the winter and 7° during the summer, and that soil temperature was 2.5° to 3° warmer in winter and 6° to 7° cooler in summer at a depth of 12 inches. The air humidity was 10 to 12 per cent higher in cover-crop orchards, and evaporation was considerably less than in others. A study of the root systems of citrus trees showed that the majority of the feeding roots of the orange and grapefruit were in the first 2 feet of soil.

According to the California station, the June drop of citrus may be largely prevented by care in cultivation, irrigation, fertilization, and pest control. Finely powdered calcium cyanide was found to be an excellent fungicide for citrus trees.

In study of the effect of potash on the orange the Florida station found a little higher percentage of sugar where 10 per cent potash was applied, but with only 3 per cent no difference was apparent, as the result of two years' applications. There was earlier ripening of oranges where no potash was applied, but the fruit was somewhat smaller.

Dates.—A successful method of propagating the date has been devised at the Arizona station, consisting in maintaining a moist rooting medium about the base of the offshoot without detaching it from the mother palm for a period of six to eight weeks, at the end of which time it will have developed roots.

Grapes.—A very promising new grape has been found by the Arizona station for the southern part of the State, with a high color, excellent flavor, and fine shipping quality, which is immune to the attack of June bugs. There are few varieties in southern Arizona that combine so many desirable commercial features. The station found that a light soil gives sweeter grapes than a heavy soil.

Experiments with rooting cuttings of *Vitis rotundifolia* at the Georgia station indicated that winter cuttings are best, no summer cuttings having formed roots. At the Illinois station roots of the grape were found to extend to a radius of 23 feet and to reach a depth of 9 feet.

Cane-pruned vines have given better results at the Nebraska station than spur pruned in the percentage of buds that produced fruit, in the number of clusters produced, and in the size of the clusters.

The pigment in dark blue grapes was found by the New York State station to be a monoglucosid, splitting on hydrolysis with acids into glucose and the color base.

Small fruits.—Raspberries with straw and manure gave an increase of over 50 per cent in production over unmulched vines, at the Illinois station, and the berries were of better quality and firmer. Foliage was retained longer on mulched gooseberries and currants than on unmulched.

In experiments with brambles, the Massachusetts station found that sulfate of potash produced hardier plants than the muriate and also gave better color and vigor.

Strawberries responded better to sulfur than to phosphorus applications, in experiments at the Missouri station.

Winter injury and hardiness of fruits.—Tests with apple seedlings at the New Hampshire station showed that if these are frozen and placed in a warm place at once they are severely injured, but if they are kept at 0° C. for a month or more fairly good results are obtained. The top parts of the roots of seedlings were found to be hardier than the lower parts. No correlation was found between the size of root and the injury done. Frozen roots that were not injured grew faster than unfrozen checks. The xylem cells were first discolored, then the phloem, this being shown by dark rings on cross sections of roots. Those showing a double ring on cross section were markedly injured, while

those showing a xylem ring only inside the cambium, were not injured. Injury increased with the length of exposure to low temperatures, and the injury was more severe with quick freezing than slow. When roots were dried for 24 hours they became more resistant. Freezing injury was due to the exhaustion of water from the protoplasm. When plants were frozen in sand the amount of injury increased with the quantity of water present. A difference in root hardiness of varieties was found, Duchess and Hibernal proving to be the most hardy in a 3-year trial. The latter may be used as root stock to advantage, but Duchess has no value for this purpose. In freezing, water went out of the cells and froze in the intercellular spaces. Drying gave practically the same effect as freezing. Seedling roots imbedded in sand, both dry and containing different quantities of water and subjected to a temperature of —8° C. for nine hours, showed about 13 per cent less injury in dry sand than in wet or medium moist sand. There was found to be no greater tendency for small roots to be injured than large ones of the same age. Small young roots, however, were found by the Nebraska station to be more susceptible to cold than larger, older ones. The tops of some varieties of apples were found to be more subject to winter injury in the nursery than others. The moisture content of orchard soil did not greatly influence the minimum temperature that was reached in midwinter at several inches below the surface. Freezing temperatures were reached somewhat sooner in early winter in dry than in wet soil; but in early spring wet soil remained at or near the freezing point, while the dry soil had a mean temperature of 34° F. Wide variation was found in hardiness of apple stocks to winter injury.

The Missouri station found a correlation between the rate at which tissues dry in the oven and hardiness, hardy tissues drying more slowly owing to the water being held in a colloidal condition.

Fruit bud formation.—Buds of the gooseberry and currant were found by the New York Cornell station to differentiate into flowers for the next season, about the middle of August. Blackberry buds showed the differentiation early in September and black and red raspberries did not clearly differentiate until early spring. In bramble fruits all buds appeared to be potentially fruit buds.

Studies of the effect of blossom bud formation in plums at the Wisconsin station showed that partial or complete early defoliation had a marked inhibiting effect, and buds and spurs formed at the defoliated nodes were noticeably smaller than the average, there being evidence of mass or cumulative influence on bud formation extending into the next season. The defoliated nodes contained decidedly less nitrogen than those not defoliated.

Data secured at the New Hampshire station showed that during the period of most active fruit bud formation, the spurs on the nonfruiting sod plats, 10 per cent of which formed fruit buds, were lowest in total nitrogen; those on fruiting sod plats, none of which formed fruit buds and those on the nonfruiting nitrate plats, 44 per cent of which formed fruit buds, were medium in nitrogen content; and those of the fruiting nitrate plats, 0.5 per cent of which formed fruit buds, were highest in nitrogen. At the same time the spurs from the nonfruiting sod plats were highest in starch, those from the nonfruiting nitrate plats, medium in starch, and those from the fruiting sod plats and fruiting nitrate plats were lowest in starch. An examination of the starch and total nitrogen for the entire season showed that the spurs from trees grown in sod were in general lower in total nitrogen and higher in carbohydrates than the spurs from trees grown on the nitrate plats.

Fruit products.—The California station found that fruit can be frozen solid and kept in fresh condition without loss of flavor for a year or more. The texture is injured somewhat, but it is fully as good for jams, ice cream, and other purposes.

In studies on fruit jellies at the Delaware station, the essential factors in jellying were found to be pectin, sugar, and acid. The formation of fruit jellies was not correlated with total acidity but with active acidity or hydrogen-ion concentration, the minimum hydrogen-ion concentration at which jelly formed being pH 3.46. Jelly formation occurred irrespective of the quantity of pectin present when the minimum hydrogen-ion concentration was reached, but there was a minimum amount of pectin necessary to produce jelly. With pectin, sugar, and water maintained constant, the character of the jelly formed was determined by the hydrogen-ion concentration, the jelly becoming stiffer as

this increased. Tartaric acid was the most efficient of the acids that are commonly present in fruit juices used for jellies, malic acid being next and citric acid least efficient. A study of the sugar factor showed that the quantity of this could be varied over a wide range, but the percentage of sugar in a finished jelly was fairly constant, being approximately 70 per cent by weight. Increasing the hydrogen-ion concentration increased slightly the percentage of sugar in the finished jelly. The least percentage of sugar possible for jelly formation was 64.1 per cent, but jellies made with the lower percentages were tender and weak, regardless of the hydrogen-ion concentration. Jelly formation may occur in the presence of a saturated solution of sugar. The sugar-holding capacity of a jelly increased materially with increase in hydrogen-ion concentration. At pH 3.4 it was not possible to add more than 125 to 130 grams of cane sugar to 2 grams of pectin and produce a jelly, but at pH 3.1 a jelly could be formed upon the addition of 170 to 180 grams of sugar to the same amount of pectin. Jelly formation appeared to be a precipitation of the pectin in a saturated or nearly saturated solution of sugar, the precipitation being determined by the hydrogen-ion concentration.

Vegetables.—Tests with asparagus at the Rhode Island station showed that on soils of the same reaction sodium chloride is more useful than the carbonate in replacing potash.

Studies of inheritance of size of beans at the Maine station showed that all pigmented varieties are larger than nonpigmented and there appeared to be a definite linkage. Resistance to mosaic was also found to be linked up with color and size. F_3 families were all found to be either resistant or susceptible, showing segregation. Results with Lima beans at the Illinois station showed that the inoculation of seed with pure cultures of the bacillus which causes nodules on cowpeas increased the yield of beans.

Tests with cabbages at the Pennsylvania station indicate the water-holding capacity of the soil to be a leading factor in regulating the solidity of the heads. The presence of considerable amounts of sand in a soil led to the production of larger roots and smaller tops than was the case in rich soils. It was found that, with cabbage, treatment which gave the largest total yield also gave the largest early yield and the greatest production of early heads; but with the tomato, the largest proportion of early fruit, though not the heaviest weight, was always obtained from half-starved plants. The total yield may be reduced by frost if a fertilizer is applied that produces very heavy foliage growth, under which the fruit ripens slowly.

In seed-bed plantings of celery from December 10 to February 25 at the New York Cornell station, some were frozen and some died; but all the early plantings went to seed regardless of treatment, freezing and drying having no effect.

Experiments in the forcing of Witloof chicory at the Illinois station indicated that medium-sized roots are best for this purpose; and although freezing causes them to rot, they may be held in storage at 31° F. to keep them dormant and are then in excellent condition for forcing.

Applications of acid phosphate were found to hasten the maturity of lettuce by three weeks at the Arizona station.

Muskmelons started under glass at the New Jersey stations showed a gain of two weeks in time of ripening over those from seed planted in the field and gave an increased yield of about 750 melons per acre.

Experiments on the irrigation of canning peas at the Utah station showed that two irrigations instead of one increased the yield 51 per cent and three irrigations 92 per cent.

Experiments in forcing rhubarb at the Illinois station indicated that differences in temperature had a marked effect on the yield and color and that differences in watering influenced the development of the crop. The quality of forced rhubarb was much superior to that grown out of doors.

Sweet corn crosses, Black Mexican and Golden Bantam with Crosby, have given excellent results in the F_1 generation at the Maine station. Observations at the Indiana station showed that large and small kernels within a variety caused a variation of about five days in time of reaching the canning stage, the corn from larger kernels being earlier, more uniform in maturity, and slightly heavier in yielding ability than that from the smaller kernels.

Studies of the changes in the amount and character of the carbohydrates in sweet corn and methods of accurately determining these were reported by the Maryland station. Sugar and starch and the relative proportions of these two in early and late corn at different stages of growth were determined and the rates of

ripening at the prevailing mean temperatures were definitely worked out as a basis for forecasting the date and duration of the best canning stage for sweet corn. It was found that the reliability of the nail test was dependent largely upon the rate of ripening and of loss of water by evaporation. The rapid deterioration of corn in warm weather after it had reached its prime condition for canning was shown.

Sweet-potato fertilizer tests at the New Jersey stations showed the organic sources of nitrogen to be equal to the mineral sources from the standpoint of yield. Sulfate of ammonia proved to be superior to nitrate of soda. Potash was a very essential element. The fertilizer mixture as well as moisture conditions had a marked influence on the shape of the sweet potato. At the Arizona station pruning sweet-potato vines, as is commonly practiced, was found to reduce the yield 50 per cent.

At the New Hampshire station, potash used in connection with phosphoric acid on tomatoes delayed maturity and decreased yields, there being an increase of only 9.4 per cent over the check, compared with 141.8 per cent where acid phosphate was used alone.

Walnuts.—Moldy nuts were found by the California station to result from allowing them to remain in the husk after they were ripe. Proper irrigation corrected this, causing the nuts to drop out early, giving less "stick tights."

Hydrangeas.—The determining factor in the color of hydrangeas was found by the New Jersey stations to be the reaction of the soil solution, an alkaline soil giving a pink color and an acid soil a blue.

Tung oil trees.—Experiments at the Florida station showed that seed of the tung oil tree should be planted in late January or in February to avoid frost injury to the young plants. Ordinary methods of root cuttings proved almost a complete failure, but both patch and sprig buds made good union and subsequent growth. Three insect pests have been observed, the cottony cushion scale, *Lantana* sp., and nematodes. The great variation in the bearing qualities of this tree makes successful budding especially important, as it makes possible the propagation and planting of trees of known bearing character.

Pruning.—In a study of the physiology of pruning at the California station, it was found that pruning weakens the concentration of the sap by stimulating vegetative growth, and high concentration bears a relation to fruit setting.

Observations on pruning at the New York Cornell station indicated that cutting off low limbs reduced bearing from one-third to one-half.

Spraying and dusting.—A dry-mix sulfur-lime has been developed by the New Jersey stations as a summer fungicide for tree fruits that is being widely used with much success, largely taking the place of self-boiled lime sulfur.

A spreader consisting of 1 gallon of sour milk and 2 ounces of bicarbonate of soda added to 200 gallons of lime-sulfur mixture gave as satisfactory results at the Iowa station as commercially prepared caseinate and was much cheaper.

Experiments with radishes under normal, light, and heavy shading at the New Hampshire station showed that shading did not increase the sensitiveness of the plant to Bordeaux, and the degree of alkalinity of the Bordeaux had no material effect.

DISEASES OF PLANTS

Apple Diseases.—Studies on the control of blister canker at the Iowa station have shown the best treatment to be to cut out the canker with a gouge and mallet and paint the wound with white lead and linseed oil, to which is added 0.5 ounce of powdered mercuric chloride to each 2 quarts of paint. Ordinary roofing paints may be used, as the coal tar base of these seems to be very toxic to the blister canker fungus and does not hurt the freshly cut bark. The New York Cornell station reports a new Fusicoccum canker of the apple, affecting nursery stock in storage and trees in the orchard. A new species, *F. pyrorum*, is found to be the cause.

Satisfactory control of apple blotch was secured at the New Jersey stations with two applications, in addition to the regular spray calendar, of commercial concentrated lime-sulfur, 1:40, made at 7-day intervals following the fifth summer spray made four or five weeks after the petals fall. The Indiana station, on the other hand, reports that lime-sulfur is not so reliable as Bordeaux, of which even the weaker mixtures prove effective for the control of this disease.

The organism *Sphæropsis malorum* has been isolated from frog-eye of the apple by the Pennsylvania station, but artificial infection has not been successful. The use of lime-sulfur spray reduced the disease from one of the worst to one of minor importance.

In studies of apple measles at the New Mexico station, no organism was isolated and the trouble is thought to be one of nutrition or lack of moisture, accompanied by accumulation of salts. Attempts to transmit the disease by inoculation and grafting were not successful.

Cedar rust, the alternate form of apple rust, has been successfully grown by the West Virginia station on infected cedar leaves removed from the tree and kept in an ordinary nutrient solution containing glucose. Such cultures have been kept alive for four months.

Field and greenhouse studies on apple scab at the Wisconsin station show that temperature and moisture cause important variations in the development of the causal fungus and in the susceptibility of the host plant at critical periods, as well as in the inception and development of the disease and the action of the fungus. The addition of a prepink application of a suitable spray to the usual program has given satisfactory control. The importance of the prepink spray was also emphasized by results obtained at the Michigan station. At the Massachusetts station, lime-sulfur and Bordeaux, if thoroughly applied as a spray, gave 100 per cent control. Dusting did not control the disease. Copper fungicides burned the foliage, but could be used up to the pink spray, after which lime-sulfur was best. Sulfur was not effective at low temperatures. Results of two years' work at the Pennsylvania station showed the superiority of lime-sulfur sprays over sulfur dusts in controlling the scab. The most effective sprays were those containing nicotine as well as lime and sulfur. The experiments also emphasized the necessity of timely spraying, especially the value of a prepink spray. At the Virginia station it was found that rainfall is necessary to bring about the discharge of ascospores.

Seedlings of known fire blight resistant stocks of apple, pear, and quince at the Tennessee station, open fertilized in an orchard containing susceptible varieties, exhibited a high degree of resistance, indicating that this factor is dominant.

Pear Diseases.—Studies on pear leaf spot at the New Jersey stations indicated that four summer applications of self-boiled lime-sulfur, in addition to the petal fall spray for the curculio and codling moth, will give satisfactory control of this disease.

The pear blight organism was found by the California station to occur in the outer bark rather than in the cambium, and it may therefore be killed without injury to the tree. The best results were obtained with zinc chloride applied after scraping off the rough bark, as a 50 per cent solution, with the addition of glycerine to prevent drying.

Studies on European canker at the Oregon station show it to be particularly destructive to thin-barked pear trees and it spreads rapidly. A fair degree of control was secured by spraying with Bordeaux previous to the fall rainy season. The early spore stage has been found in young cankers, which helps diagnosis.

Peach yellows.—Studies on this disease carried on at the Delaware station showed that the carbohydrate synthesis of "yellows" wood is not materially different from that of normal wood, but there is a retardation in the diseased host of the utilization of the carbohydrate products previously formed. In 2-year yellows wood there was a more pronounced and permanent deposition of gum in the medullary rays. The cellular units in the diseased plant were smaller and the tissues in the wood and leaf were greatly reduced in comparison with the normal. No infections resulted from inoculations of infusions of fruit, leaves, and limbs of diseased peaches, indicating that the disease may be carried otherwise, and possibly the causal organism may go through a part of its life in some insect. Pollen from infected trees, when applied to healthy trees, failed to set any fruit. It is believed that the curculio may be closely connected with the trouble.

The Verticillium causing eggplant wilt is, according to the New Jersey stations, apparently the same as that found on okra and on the peach, although transfers from the peach were not successful. The disease appears to be most severe on alkaline soils. If infected limbs and trees are cut out of a peach orchard, it disappears.

Cherry leaf spot.—It was found at the Wisconsin station that the causal fungus of this disease passes the winter in old leaves on the ground, and in the spring produces spores which pass through the air to the cherry. It was found to be unnecessary to apply the preblossom spray formerly considered to be essential by some growers.

Citrus diseases.—Studies at the Florida station showed that citrus seed infected with citrus canker organisms did not produce canker-infected plants. The longest time the organism was observed to live in unsterilized soil

was one week, but it lived and remained viable for many months in sterilized pine shavings and was observed to live for some time in both sterilized and tap water. Spores of the organism in cultures over a year old were still alive and viable. Some evidence was secured indicating that bees may act as carriers of the disease. In studies on the control of citrus melanose and stem end rot, at the same station, one application of a spray of 3–3–50 Bordeaux plus 1 per cent oil emulsion, applied from 10 to 20 days after the blossoms had fallen, more than doubled the number of bright fruits. The cost was from 8 to 13 cents a tree and there was a net gain of 50 cents a box profit from spraying.

The cause of the internal decline of lemons was found by the California station to be abnormal water relations, due to withdrawal from the fruit by the leaves during hot summer months. Even under heavy irrigation the leaves could not pump water up fast enough and in hot winds they wilted. Internal decline after picking or in transit is thought to be an Alternaria rot induced by any weakness in the lemon. Infection occurred in the early stages, the mycelium working its way into the fruit. It did not grow in the green lemon, but as soon as physiological changes took place in storage it started.

Disease resistance in plums.—An examination of 11 varieties of plums at the Minnesota station, in relation to resistance to the brown rot fungus (*Sclerotinia cinerea*) showed that those varieties containing 6 per cent or more of fiber on the dry basis were comparatively resistant and those containing a less amount were susceptible.

Diseases of vegetables.—A new organism was found in the bacterial spot of Lima beans by the Wisconsin station, which has been named *Bacterium viridifaciens*. All varieties of Lima beans tested were susceptible. The disease was especially severe with heavy rainfall and a moderately high temperature. It is believed to live over winter in seed and refuse. Data secured at the New York State station showed that the date of planting bears an important relation to the susceptibility of beans to bacterial blight, late-planted beans suffering less than early-planted. The Colorado station found much difference in the susceptibility of varieties of beans to bean rust. Several pintos were almost immune.

Cabbage yellows has been extensively studied at the Wisconsin station. The organism, *Fusarium conglutinans*, was found to be especially destructive in hot, dry weather, with little or no development, even on the "sickest" soils, in cool, moist weather. The optimum temperature for the fungus was found to be 25° to 27° C. A soil moisture content of 15 per cent was most favorable for this fungus and 19 per cent for the growth of cabbage seedlings, in a soil having a water-holding capacity of 46 per cent. Early seeding insured most favorable conditions for resistance to the disease. All plants remained healthy in a sick soil, below 17°, many were resistant at 17° to 23°, and some at higher temperatures. Susceptibility to disease increased with age.

Studies on the downy mildew of the cantaloupe at the Delaware station showed that the effects produced by the fungus causing this disease, *Pseudoperonospora cubensis*, is apparently the result of a toxin, perhaps an enzym. Light, even dustings with copper salts, arsenic, or nicotine controlled it except when weather conditions favored the disease.

In investigations on carrot blight at the Massachusetts station, an organism, *Cercospora apii carrotiæ*, was found and grown in cultures from which the disease was reproduced. The fungus did not germinate if immersed in water, but in a moist atmosphere it germinated at 20° C. It was very resistant to copper fungicides.

Cauliflower black rot appeared, from studies at the New York State station, to survive and be carried over winter on white cabbage and Brussels sprouts, the cauliflower itself not surviving the winter. Plants grown to maturity under cheesecloth largely escaped the disease, while those not so protected were severely attacked. Spraying the plants in the seed bed or field with Bordeaux injured them.

Satisfactory control of lettuce drop was secured by the Massachusetts and Pennsylvania stations by treatment with commercial formalin, which also stimulates the plants, 4 pints to 50 square feet of soil in the coldframes being recommended by the latter station.

The fungus causing onion smut was grown in media ranging from pH 3.5 to 9.5 at the Massachusetts station, showing that acidity is not the controlling factor. By using a stronger formaldehyde solution than has been recommended, as high as 95 per cent, good control was secured.

In studies on pea root rot at the New Jersey stations, seven organisms were found, including two Fusaria, a Rhizoctonia, and unidentified organisms. It appeared on the roots soon after the peas were up, as a rule, and its most injurious effects were noted at blossom time. It may be carried from field to field by soil particles and the organism may survive in the soil for long periods without peas. It was worse on light soils. As yet no control has been found. The Utah station isolated four species of fungi from this disease from infected soil, including *Corticium vagum*, *Pythium* sp., and two Fusaria, but it is not believed that these are responsible for the major part of the trouble found in the field. Later a fifth species was found, an *Aphanomyces* sp., which it is believed is mainly responsible. This organism causes a hardening and yellowing of the peas and lowers the grade. The station also found two fungi associated with pea black leaf, a Fusicladium and a Phyllosticta, which appear to be forms of the same fungus. All attempts to cultivate the causal organism have failed.

Studies of the crown rot of rhubarb from four localities by the Pennsylvania station showed it to be caused by different species of Phytophthora, but that *P. cactorum* is the only species present in Pennsylvania. Setting disease-free roots in a new location is the most practical method of control.

A new species of spinach wilt, caused by *Fusarium spinaciæ*, was found during the year by the Idaho station. It destroys the root system of the plant. The Texas station reports that this disease has been serious in the State for several years. New Zealand spinach was found to be 100 per cent resistant to the wilt and also to summer heat.

Sweet potato scurf or soil stain caused by *Monilochætes infuscans* has been studied at the Delaware and New Jersey stations. The former station found it could be fully controlled by disinfecting the seed with corrosive sublimate except in fields that had been cropped with sweet potatoes for a number of successive seasons. Infected seed that had not been treated produced heavily infected sprouts, with little possibility of normal growth. The disease was more prevalent where the humus content of the soil is largest. At the New Jersey stations good control was secured by broadcasting sulfur at the rate of 400 to 600 pounds per acre. Yellow Jersey and Nancy Hall were very susceptible and Red Brazil, Dahomey, Dooley, Pumpkin, and White Yam, resistant.

Study of sweet potato pox at the Delaware station failed to associate *Cytospora batata* with the disease. Infection seemed to occur in the field. Sulfur-treated plats gave an increase of 98.8 bushels over untreated plats, this treatment being most successful when inoculated sulfur was applied broadcast or drilled. Crop rotation is recommended to reduce the prevalence of the disease. The New Jersey stations also report that from 400 to 600 pounds of sulfur gave good control.

The soil rots of sweet potatoes were found by the Delaware station to occur in direct relation to soil temperature and moisture. When manure was applied, soil rot was more prevalent and it appeared that this, as well as plowing under a green cover crop, influenced the moisture content of the soil sufficiently to greatly increase the disease. Studies of stem rot caused by *Fusarium batata* and *F. hyperoxysporum* at the New Jersey stations showed that heavy applications of manure increased the disease. Seed selection gave no results, but treatment of infected potatoes with corrosive sublimate was important in preventing dissemination of the disease. It was worse on sandy loam soils. Dooley, Triumph, White Yam, Red Brazil, Dahomey, and Pumpkin appeared to be entirely or nearly immune.

In tests of sprays for the control of leaf blight and bacterial soft spot of the tomato at the Virginia station, good results were obtained both with Bordeaux mixture and soap-Bordeaux mixture, the latter being a little more effective. Copper-lime dust was not so effective as soap-Bordeaux spray in the control of leaf blight, but it greatly reduced loss of fruit from soft rot. At the New Jersey stations four or five applications of Bordeaux greatly reduced leaf spot caused by *Septoria lycopersici* and early blight caused by *Macrosporium solani*. Good results were secured with a dust consisting of 20 parts monohydrated copper sulfate and 80 parts of lime.

Studies of the strains of tomato and potato Phytophthora causing blight, at the West Virginia station, showed them to be distinctly biologic forms although closely related. It has been demonstrated by the Indiana station that tomato mosaic is carried over in the field by the perennial ground

cherry. When the growth of this plant was kept down, there was a 2 per cent infection as compared with 14 per cent in an uncleared field.

It was found at the Texas station that Fusarium wilt of tomatoes may penetrate to the interior of the seed. The fungus was isolated only from ripe fruit. Vines or roots which had been killed and dried for nearly four months still yielded virulent growths of the Fusarium fungus. At the Missouri station the capacity of the organism to produce infection was found to be greatly reduced or inhibited by increased acidity of the soil.

Flower diseases.—Snapdragon rust was controlled in a warm greenhouse at the New Hampshire station by sulphuring, but in the open the control was not good even though a temperature of 22° C. or above was maintained for at least four hours each day by moving the plants into the greenhouse. However, plants growing in the field were protected from the rust if they were covered by bell jars at night. At the New York State station Septoria leaf spot of China asters was found to be seedborne and was controlled by sterilizing the seed bed with corrosive sublimate.

Forest tree diseases.—The Connecticut State station found that it does not pay to cut out white pines affected with blister rust, as the disease is self-limited. Infection was found to be through the stomata of the leaves in the late fall. Inoculations in different species of pines showed that the disease will attack other 5-needle species. The fungus grows in the needles and works down to the stem the next season. Ribes appears to be a secondary host, and its eradication for a distance of 500 yards from a white pine stand is considered fairly safe. The disease is probably windborne from Ribes to pine and vice versa.

Cereal diseases.—In extensive studies of blight of cereals at the Wisconsin station, it was found that *Gibberella saubinetii* grew normally in pine cultures over a wide range of temperature, from 3° to 32° C. The optimum temperature for spore formation and germination was 24° to 28° C. Seedling blight of wheat developed on young plants at high soil temperatures and on corn at low soil temperatures. Lowering the soil moisture to a point where normal growth of the seedling was inhibited predisposed both wheat and corn to attack. Wheat seedlings grown with a low light intensity blighted badly; those with a high light intensity and a longer period of illumination did not blight. Chemical studies showed that at low temperatures wheat seedlings separated from the endosperm were high in sugars, but that corn seedlings were low in sugars. The dextrins or gums were also lowest at low temperatures. The relatively high content of available carbohydrates in the wheat seedlings at low soil temperatures and of corn seedlings at high soil temperatures was found to result in thickened cellulose walls, offering resistance to fungus penetration.

Thirty-eight biologic forms of rust, varying in virulence on different varieties, have been isolated and their distribution and methods of identification determined at the Minnesota station. Wheat infected with *Puccinia triticina* or *P. graminis tritici* showed lower water economy than normal wheat. The addition of sodium chloride or monosodium phosphate to a basic three-salt nutrient solution had no effect on susceptibility, sodium nitrate caused greater infection but increased the yield, calcium chloride and magnesium chloride appeared to reduce susceptibility, and calcium chloride reduced the water requirement. The Idaho station found *Puccinia glumarum* on 59 species of wild grasses, as well as on wheat, barley, rye, spelt, and emmer. *P. glumarum tritici* was found to overwinter in the uredineal stage on the Pacific coast and intermountain regions of the West, but not to be transmitted from one wheat crop to the next by infected seed. Cytological studies at the Minnesota station showed that the morphology of some wheats is such as to make it impossible for rust hyphæ to spread extensively within the tissue. Infection was traced in one case for a distance of 7 miles from a barberry hedge. Studies of wheat leaf rust at the Indiana station indicate a definite segregation and inheritance of resistance, and a promising start has been made in developing a resistant variety. There are several strains of the rust. Some progress has also been made in resistance to corn and rye leaf rust.

Copper carbonate was successfully used to control smut in wheat at the Virginia station, but was not so effective for oat smut as formaldehyde. At the Idaho station the highest percentage of infection of stinking smut of wheat occurred at a temperature of about 50° F. and a soil moisture content of about 22 per cent. There was a rapid decline of infection in moist

soil cultivated frequently. Copper carbonate proved a more effective treatment than bluestone. Nickel carbonate gave very good results. In a trial of a number of copper preparations for smut control at the Washington station, those with a low copper content were not so effective as the pure copper carbonates. The results indicate that 3 ounces of pure copper carbonate or 4 ounces of the weaker preparations should be used per bushel for fall seedings, and 2 to 3 ounces of the pure salt or 3 to 4 ounces of the weaker preparations for spring seedings, using heavier applications only when the seed is visibly smutted. Control of bunt with anhydrous copper sulphate was much poorer than with copper carbonate.

A study of two biologic forms of the fungus causing stem rust of wheat (*Puccinia graminis tritici*) at the Nebraska station showed that in no instance was the general type of infection changed on different wheat varieties by any environmental factors, including soil temperature and moisture and air temperature, by the source of inoculum, or by the source of seed of the host. The optimum temperature for the development of the disease was between 20° and 25° C. No infection occurred at 10° or below and only a few plants were infected at 15° or 30°. Studies of the viability of the uredospores under field conditions showed that they do not overwinter at the station. The highest germination and longest viable period of the spores was at low temperatures and medium relative humidity, and they died quickly with high temperature and humidity. Some evidence was obtained by the Colorado station that the uredospore stage can live over winter on stubble and wild grasses without the barberry being present. Germination of spores from rusted grasses kept over winter in plats was secured as late as April, indicating that under mild winter and good snow cover conditions the uredospores will winter over in Colorado as they do in Texas.

In a study of crown rust the Iowa station found that many wild and cultivated species of buckthorn (Rhamnus) may serve as hosts for the disease during part of its life history.

Marquis and durums as a group were found by the Minnesota station to be very susceptible to wheat scab; Preston, Haynes, Glyndon Fife, and several others are much more resistant. Results obtained at the Kansas station indicate that "take-all" is not spread by seed, but seems to be carried over chiefly in the soil. Continuous wheat shows the worst infection. Lime and gypsum appeared to increase infection, as did early plowing and disking fields.

Helminthosporium sativum was found by the Minnesota station to be widespread, causing many diseases and affecting all parts of the plant. It has many hosts and biologic forms and manifests itself in various ways. It overwinters in seeds and in plants in the field, and sporulates on dead and decaying plants. It is difficult to control, the development of resistant varieties being the most promising method.

Besides organisms previously reported, the Kentucky station found that a Helminthosporium was present in 25 to 50 per cent of the seed corn examined, a Macrosporium in a small per cent, and a Sclerotium in a few. All of the samples examined were found to be infected. Some seeds which appeared to be sterile when cultivated on plates showed infection on microscopic examination. It was found that by moistening the seed, placing it in a vacuum tube, and pumping out the air, the seed coat layers were pressed together, sealing the organisms between the layers, and the seeds could not then transmit the disease. At the New Jersey stations *Fusarium moniliforme* and *Cephalosporium* sp. were the most active organisms found, and *Gibberella saubinetii* also was common. The disease was considerably reduced by seed selection. Alkaline soils were found to be favorable to the disease. Flinty types of corn were found to be most resistant. The only organism found in this disease at the Ohio station was *Diplodia zeæ*, but cross-inoculations with this organism secured from ear rot did not produce a typical root rot. On undrained soil there was less difference in yield between diseased and disease-free seed than on drained soil. No relation was found at the Delaware station between the flora of corn-sick soils and the cause of root rot, the flora being practically the same as that of nonsick soils. *Fusarium moniliforme* was found in some seed but was more or less inactive. *Gibberella saubinetii* was very active, as was *Diplodia zeæ.* The fungus reported from India as *Cephalosporium sacchari* was found by the Indiana station to be a Fusarium, but a nonpathogenic Cephalosporium was found. Attempts to reproduce the disease with

the organisms commonly associated with it, *Fusarium moniliforme* and *Gibberella saubinetii*, were not successful in soils that were high in nitrates. The rots were found to be most abundant in acid soils. Potash and phosphate prevented the invasion of iron by stimulating growth. Iron concentrates in the phloem tissue were found to precipitate the protoplasm, the cells breaking down. The effect of aluminum was nearly the same as iron, but it was more generally distributed through the plant. Phosphorus controlled aluminum injuries. Corn grown in an acid soil, with much available iron, often blackened when canned. Corn withstood an acidity of 3.5 when no available iron or aluminum was present. Calcium made potash unavailable, and as potash prevents nodal accumulation of iron, corn should not be too heavily limed. Susceptibility to root rot and the various strains of Diplodia and rusts is inherited. The absorption capacity of different inbred strains of yellow dent corn was found to vary widely, as reflected in the ash analysis, ranging in phosphorus absorption from 0.39 to 1 per cent of the dry matter, in iron from 0.026 to 0.063 per cent, and in potassium from 0.47 to 5.59 per cent (as oxides).

The optimum temperature for the development of ear rot of corn was found by the Iowa station to be 30° C. The disease gains entrance by nodal infection, not through the roots. The fungus of dry rot of corn (*Diplodia zeæ*) may attack the plant through the silk and ear tips; but the nodes of the stalk, the ear shanks, and butts of the ears are the chief points of attack. The fungus may spread in seed corn while curing or in corn cribs during damp weather. High temperatures favored the spread. Planting infected seed resulted in a decreased stand and lower yield. Infected seed were difficult to detect, except by germination tests. Long rotation, early field selection of seed, and germination tests appear to be the most practical means of control. It was found that the spores of corn smut germinated best at a high temperature, about 30° C., and on solid medium.

Untreated corn seed was found by the Tennessee station to be 100 per cent infected with *Fusarium* sp. Presoaking the seed, followed by a brief immersion in hot water and corrosive sublimate solution, gave 97.5 per cent clean plants.

Early plantings gave best results at the Illinois station with good disease-free seed, but with diseased seed later plantings were better. Diplodia was worse in early plantings if there was much moisture.

Cotton diseases.—In studies on the effect of alkali on resistance of Pima Egyptian cotton to blackarm or angular leaf spot, at the Arizona station, it was found that infection lasted over in the seed but not in the stalks left standing in the field. Seed treatment with sulfuric acid gave excellent results. Plants on alkali soils were more woody and hence less susceptible to injury by blackarm. Seeds soaked in cultures of the organism gave only about 3 per cent of infection in alkali soils, as compared with 30 per cent in alkali-free soils. Wild cotton is found to be susceptible to blackarm.

Cotton root rot has been shown by the Texas station to be due to a Phymatotrichum. The fruiting stage of the organism was secured in pure cultures. The disease appears to be carried over on a living host, there being no evidence that it is carried in the soil. In crop rotation it was carried by certain weeds. Cotton was found to be a very important factor in carrying the organism over winter, and underground infection was active during the winter months. Early planted cotton showed a far greater percentage of root rot than late planted. Perennial susceptible weeds, as the morning glory, help to hibernate the organism. A 2-year clean fallow did not absolutely eradicate all perennial weed carriers. The disease does not spread except by contact of roots. Cereal crops are immune, but outbreaks have followed corn in the cockleburs and tie-vines which grow between the rows. The disease is greatly reduced in a dry year. Very little difference in resistance was found between different cotton varieties.

Flax diseases.—Studies with *Fusarium lini* at the Minnesota station showed that this will grow with alcohol as the sole source of energy until it produces about 4 per cent in the medium and then it ceases to grow because of the toxicity of the alcohol. It ferments pentoses as well as hexoses but with relatively less alcohol formation.

Potato diseases.—Investigations at the Nebraska station on the viability of the causal organism (*Bacillus phytophthorus*) of blackleg under various conditions of temperature and moisture showed it to be very susceptible to desiccation. At 100 per cent humidity it remained viable for at least eight days. At 90 per cent humidity, with a temperature of 25° C., it re-

mained viable for only three hours. At 80 per cent humidity, with the same temperature, it lived for one hour only. Inoculation experiments on tubers showed that at the optimum temperature no rotting occurred at a humidity of 40 per cent or lower. Tests at the Montana station showed that five minutes' treatment of the cut seed with formaldehyde and corrosive sublimate solutions was sufficient to kill the organism, and this had no injurious effect on the germination of the seed.

Complete control of early blight on the late crop of potatoes was secured with Bordeaux at the New Jersey stations, only 0.5 per cent of the leaves on the treated plats being dead, compared with 57 per cent in the untreated plats. Spraying gave an increase of 69 bushels per acre, but copper-lime dust gave no increase. In studies on the control of late blight at the Florida station, copper-lime dust containing 6 per cent of metallic copper resulted in an increase in yield of 25 per cent over untreated plats. Bordeaux paste gave approximately the same results but was more expensive, but homemade Bordeaux gave as good control and was cheaper than copper-lime dust.

Stem canker was found by the Wisconsin station to be stimulated to its greatest development by low temperature, and with the organism present in the seed tubers the young shoots may be wholly destroyed or form weak plants. With higher temperatures the shoots escaped injury, and therefore early plantings, while the soil is cool, may suffer more than late plantings.

Studies on potato leaf roll at the Indiana station showed that if a disease-free hill became infected during the current season the yield was not reduced, but seed from this hill planted next year gave a decided reduction. The disease can not be accurately identified the first year in the field, and in selecting high-yielding hills these may be infected. The Vermont station has demonstrated that there is a physiological tipburn distinct from leafhopper tipburn. The physiological disease begins at the tip and margins of the leaf, while hopperburn may appear anywhere on the leaf.

Studies on potato scab at the New Jersey stations showed good control on lighter soils by the application of 300 pounds of sulfur, which was as efficient as 600 pounds and the residual effects in increasing soil acidity were less marked. Broadcast applications just before planting gave the best results. Too much sulfur produced harmful effects, but in heavy soils it may be used up to 500 pounds, depending on the amount of infection. Sodium nitrate in a complete fertilizer was found to increase the disease, and ammonium sulphate to decrease it. On the nitrate plats 62 per cent of the crop was unsalable, and on the sulfate plats 21 per cent. Soil moisture was shown to be an important factor, scab being most abundant on soils of low moisture content, and decreases in severity with increase in moisture. On soils with the same moisture content it was less severe on soils with a low hydrogen-ion concentration. Treated seed gave a 77 per cent clean crop, untreated seed 56 per cent, and treated seed on treated soil gave 93.9 per cent clean tubers. The Vermont station found the organism causing scab in virgin soil. The Wisconsin station found that high temperatures facilitated development of the disease, and that low temperatures lessened it.

In a study of potato wilt and stem end rot caused by *Fusarium eumartii*, the Nebraska station found that infection occurred chiefly from the soil rather than through the seed, but that infected seed produced weak plants more susceptible to infection from the soil. The organism produced a toxic substance, evidently pectinase, capable of killing the host in advance of the organism. The optimum temperature for the disease was 20° to 24° C. One form of wilt was caused by *Fusarium oxysporum*, different strains of which were found to vary as much as 5° in optimum temperature for growth. The potato was found to be most susceptible to infection during its early stages. Temperatures of 18° and below, as well as constant low moisture, were unfavorable to the disease. Vascular discoloration of tuber was observed in the absence of any organism. Verticillium wilt of the potato was found by the Oregon station to spread from plant to plant underground during the growing season. The removal of plants as soon as they showed signs of wilt tended to check the spread somewhat, but it was better not only to remove the affected plants but also the plants on both sides in the row. A 4-year rotation appeared to be effective in controlling the disease. Infection occurred through the roots and was found deep in the soil. Storage rots were found by the Montana station to be due in the majority of cases to *Fusarium trichothecioides*

and *F. solani*, and field wilt is usually caused by *F. oxysporum* var. *asclerotium*.

Seed treatment for Rhizoctonia infection of potatoes with the standard corrosive sublimate solution gave excellent results at the Washington station, and seed selection produced as good results as treatment of infected stock. Copper carbonate dust gave no control. Studies at the Utah station showed the danger of accumulation of the fungus in the soil when planted successive years with infected seed.

Potato mosaic was apparently completely eliminated at the Kentucky station in two seasons from seed stock which at the beginning was infected in varying amounts up to 95 per cent, by taking a single seed piece from each tuber and planting in early April, the remainder of the tuber being numbered and placed in cold storage for late summer planting. All plants showing signs of mosaic were noted and the corresponding tuber eliminated. No mosaic appeared in the tubers thus selected. On repeating this the second year, the crop was free from the disease. The Utah station distinguishes two distinct types of mosaic, one characterized by definite mottling with little or no dwarfing and one by prominent mottling, crinkling, and serious dwarfing. The New York Cornell station found a new host for potato mosaic in *Nicandra physalodes*, the apple of Peru. Tobacco mosaic is not transmitted to this plant. Neither hot air nor hot water treatment was successful in controlling mosaic or leaf roll of the potato. Observations at the Nebraska station showed that mosaic symptoms were masked at temperatures above 70° F. and were increasingly evident as the temperature dropped, but the effect of temperature decreased with the age of the plant and the severity of the disease. High sunlight intensities and low moisture were also correlated with the masking of symptoms.

Studies of the degenerative diseases of the potato, at the Maine station, of which there are at least seven, including leaf roll, streak, curly dwarf, spindle sprout, and mosaic, of which three distinct types have been found, showed that these can be disseminated by tuber grafts, stem grafts, leaf mutilation, rubbing in the juice of infected plants, and by at least two species of aphids. These diseases of the potato do not seem to be so contagious as the mosaic of tobacco, cucumbers, or tomatoes. The same disease does not act in the same way on different varieties of potatoes. Curly dwarf and spindle tuber are the only ones that can be detected in the tuber and these only after the first year. Hill selection did not help in improving the crop, as apparently healthy hills showed the disease next year. A distance of 200 feet from an infected field was not found to be safe for a new field to be planted, and in one case 700 feet was not enough. Aphids appear to be the principal means of transmission of the disease. There may be other insects that transmit the disease, but they have not been observed. The potato plant appears to get more resistant as it gets older. The Nebraska station found a type of degeneracy very similar to or identical with spindling tuber to be present in the State, manifesting itself by a stiff upright habit of growth and an elongation of the tubers. Strains affected by it never recover, but become progressively weaker. It is perpetuated through the tubers and appears to be transmitted from plant to plant in the field. Irrigation produces conditions more conducive to the rapid increase of this degeneracy than dry-land culture.

Evidence has been secured at the Maryland station that spindling sprout and other degenerative conditions are due to lack of some unknown growth-promoting substance.

A new disease, which has been named " spindle tuber " and which reduces the yield 50 per cent in some cases, was reported by the New Jersey stations. It is transmitted by aphids and there is no evidence that it is carried over in the soil. It is an infectious disease, but the organism has not been found. Transmission was secured by grafting in the greenhouse. Infected plants grow upright with smaller and more pointed leaves than healthy plants. The tubers are long, narrow, smooth skinned, and have more eyes than nominal potatoes, these sometimes being borne on knotlike protuberances. The shape of the tubers suggests the name. Good control can be secured by roguing, if this is done early.

In seed treatment studies at the Idaho station it was found that sprinkling the tubers with water and covering for 24 to 48 hours before treatment with either corrosive sublimate or formaldehyde increased the effectiveness of these treatments.

Tobacco diseases.—Observations made at the Kenthcky station have led to the belief that seed beds are often infected with angular leaf spot by

laborers chewing infected tobacco and expectorating in the seed bed.

The causal organism of blackshank was found by the Florida station to be *Phytophthora nicotianæ*. Progress has been made in developing a resistant strain.

Tobacco mosaic was found by the Kentucky station to be carried over winter in the root stocks of the bull nettle and several other species of ground cherry common in Kentucky. It was successfully transferred from these to tobacco and the tomato. Mosaic of the bean, red clover, soybean, and pokeweed, and leaf roll of the potato could not be transmitted to tobacco.

A survey of the Burley section of the State by the Kentucky station showed that about 60 per cent of the plantings were damaged by root rot. A resistant strain developed by the station is now being planted. The Wisconsin station found that a low temperature favors this disease.

The organism causing tobacco wildfire, according to the Massachusetts station, readily overwinters on seed from infected pods. It may also overwinter on wood out of doors. The disease has been found on plants that were originally disease-free, set out in infected soil, indicating overwintering in the soil. Incorporating macerated infected leaves in the soil and overwintering these produced the disease. Sterile and unsterilized soils were inoculated, overwintered, and planted. The sterile inoculated soil gave infection but not the unsterilized soil, indicating perhaps some natural protection. There was no evidence that infected leaves plowed under are a source of infection. Control was best secured in the seed bed by frequent spraying with copper fungicides. Selection for resistant strains is offering some promise. Studies on this disease at the Wisconsin station indicate that the organism lives over winter on or in cured tobacco leaves or refuse, other places of overwintering being of minor importance. It was found that about 100 other plants, including many vegetables and field crops, may become infected with the disease.

Root rot was found by the Massachusetts station to be the chief cause of tobacco sick soils, the rot growing on legumes used as cover crops. Thielavia appeared to grow best in alkaline soils. A lighter rot was noted on plats on which timothy had been grown. Other factors than organisms were found to play a part in making a soil "tobacco sick."

Alfalfa anthracnose.—The organism causing this disease was isolated by the Mississippi station, grown in pure cultures and found to be identical with *Colletotrichum trifolii* occurring on clover, and inoculation experiments showed that it could be readily transferred from one host to the other. No indications of biologic strains were found. No considerable resistance was found in any of the alfalfa strains tested. It was shown that when the seed was sterilized with corrosive sublimate solution, 1:1,000, for eight minutes, no disease was found and there was no injury to germination.

Soybean diseases.—Field tests at the Indiana station showed that soybean bacterial blight is introduced with the seed, and indicated that the bacteria persist over winter in the field, probably in the seed. Soybean mosaic was found to be seed borne. From 10 to 25 per cent of seed from infected plants carried the disease, which persisted for two years, and reduced the yield from 30 to 75 per cent, but did not reduce the germinability of the seed. No other host was found. Attempts to transmit the disease by means of leafhoppers and tarnished plant bugs were unsuccessful. It was eliminated by field selection of seed.

Sunflower diseases.—There was found to be very little correlation between the amount of rust developing on sunflowers and the kind of fertilizer applied, in investigations carried on at the Minnesota station. Neither spraying nor dusting with copper fungicides controlled the rust appreciably. The perfect stage of the organism causing sunflower wilt was secured at the Montana station in the greenhouse on plants brought in from the field. Several different strains of the organism were found. Seed treatment gave negative results.

Chlorosis.—Chlorosis is not a specific entity, according to the New Mexico station, there being always found a deficiency in one or more soil constituents when it occurs. The use of ferrous sulphate as a spray or by boring into the trunk was only a temporary expedient and often resulted in poisoning the tree.

Mosaic hosts.—Twenty different families of plants have been found to be subject to mosaic at the Iowa station. Cross-inoculation experiments show that it is transmissible between plants belonging to different families and may be so transmitted by insects. Plants found affected with the disease not previously reported in the State include zinnia, callendula, celery, red

raspberries, *Aquilegia cœrulea*, *Stokesia* sp., *Euphorbia preslei*, *Vernonia fasciculata*, *Verbena urticæfolia*, *Lactuca scariola*, and *Abutilon theophrasti*. Cross-inoculation experiments at the Wisconsin station were successful with cucurbit mosaic in case of nearly all species of Cucurbitaceæ except watermelons, and also Martynia, pepper, milkweed, pokeweed, green seed citron, tobacco (through pepper), potato (through cucumber), pigweed, and cultivated wild cherry.

Environmental influences.—Seedling blight of wheat and corn, due to *Gibberella saubinetii*, was found by the Wisconsin station to be dependent largely upon environmental conditions, especially temperature, the most favorable with wheat being from 12 to 28° C. and with corn from 8 to 20°. The organisms functioned at temperatures from 3 to 32°. The critical soil temperature for blight of wheat was about 12°, and for corn 20 to 24°. Late seeding reduced the disease. In Helminthosporium infection temperatures at and above 24° and a high soil moisture were found to favor infection of wheat and barley seedlings. Studies on Ustilago infection showed that high soil temperature reduced infection of oats, and when combined with a high soil moisture the fungus was practically eliminated. The minimum temperature for the germination of spores of *U. avenæ* was 4 to 5°, the optimum from 15 to 28°, and the maximum from 31 to 54°. The most favorable moisture content was 30 per cent. The spores did not germinate in an oxygen-free atmosphere. For *U. zeæ* the optimum temperature was 20 to 34° and the maximum from 36 to 38°.

Phytophthora terrestria, which has been assumed to be the same as *P. parasitica*, was found by the West Virginia station to be a separate and distinct organism, *P. capsici* having no relation to either of the two. Seven species tested did not need to be deprived of food to reproduce. Maximum reproduction was obtained in some cases where potassium or sodium carbonate was supplied.

A study of the physiology of *Sclerotium rolfsii* at the Georgia station showed it to be acid-loving, growing well in beef broth of an acid reaction but ceasing to grow when this was made alkaline.

Toxic action of copper.—Uredinales were found by the New Hampshire station to be twice as resistant to the toxic action of copper as are other fungi. Uredineospores of these fungi were three times as resistant to copper as are æceospores. The conidia of *Venturea inæqualis* were more sensitive to copper than any other of the fungus spores studied. Burgundy mixture was more toxic to the spores of *Alternaria solani* than was Bordeaux mixture.

ENTOMOLOGY

Field crop insects.—For control of the alfalfa weevil, the Idaho station found liquid arsenical sprays to be more effective than dusts. The parasite *Bathyplectes curculionis*, introduced in 1921, has become established. The Nevada station also reports that the introduction of this parasite has been successful and that it is now spread over a wide area. It is believed it will be helpful in holding the weevil in check. Life history studies of the weevil indicate that it will probably be necessary to spray twice during the growth of the first crop for its control.

The optimum date for planting corn to avoid injury by the earworm was found by the Kansas station to be May 4 for all varieties except Hildreth. The white varieties appear to be more resistant to the insect than the yellow varieties. Spraying was found to be more rapid and effective than dusting in the control of this insect by the West Virginia station. It is only necessary to make the application to the ear and silk. A combination of lead arsenate and nicotine sulphate was successful.

Studies of the European corn borer at the New Hampshire station, under conditions at Durham, showed that pupation of overwintering larvæ began May 11 and continued until the end of July. The pupal stage for males was about 20 days and for females 18 days. Emergence of adult moths from overwintering larvæ began June 2 and continued until the middle of August. The average life of the female moths from the overwintering generation was about 18 days and of the male moths about 17 days. The average number of eggs laid per moth was 451 and the maximum number laid by a single individual was 1,003. The length of the egg stage varied from 9 to 12 days. At Durham the borer can complete two generations a year. It is spreading in the State at the rate of 20 to 25 miles a season. Being a flying insect, quarantine seems to be of little value. The Ohio station found this insect extending about 35 miles into the State

and advancing about 6 miles a year. There are no indications of a second brood in the State.

Corn root worms were effectively controlled by rotations, in experiments at the North Carolina station. Numbers of root worms were found in the spring on the roots of volunteer oats at the Louisiana station, suggesting that injury to corn may be caused by larvæ that are present on the roots of grasses when the land is prepared for corn, the larvæ coming from eggs deposited before the corn is planted. Corn planted on land that had previously been in grass was more apt to be injured.

Studies on the black corn weevil at the North Carolina station indicated that early planted corn is likely to be more infested than late planted, and may thus serve as partial protection to later plantings. Seed bins, if not thoroughly cleaned, promoted infestation of new corn stored in them.

In field tests on the boll weevil at the South Carolina station calcium arsenate was very efficient, especially when applied during the middle and latter part of the summer. In the fall of 1922, 95 per cent of the weevils collected at the Mississippi station were parasitized. At the Oklahoma station, of 500 live boll weevils placed in cages in various places in the cotton section just before a killing frost 34 survived in one locality but only 1 or 2 in others. At the Texas station emergence from hibernation began the last week in February and by April 30 it was 69.5 per cent completed. The last emergence was July 13, though 99 per cent had emerged by June 3.

The adult cotton square borer, a small grayish-blue butterfly, was found by the Texas station to deposit its eggs singly on the leaves, stems, or blossoms of the cotton plant. These hatched in 2 or 3 days and the worms immediately began to feed, becoming full grown in 12 to 16 days, when they went into the chrysalis stage, which lasted from 8 to 10 days. It also fed upon the Lima bean, cowpea, and various other plants. In early June the insects were abundant on cotton, but the June and July generations were heavily parasitized. Dusting with calcium arsenate gave good control.

Sugar-cane moth borer larvæ were found by the Louisiana station feeding on the following grasses, more especially during the fall and winter months: *Panicum barbinode*, *P. gymnocarpon*, *P. dichotomiflorum*, *Paspalum larranagæ*, *Holcus halepensis*, *Andropogon glomeratus*, and volunteer rice. Soaking seed cane in water at 50° C. for 20 minutes was effective in controlling both the case borer and mealybug, and the cane was not harmed unless the eyes were soft and ready to sprout. Temperatures lower than 50° were not effective in destroying the mealybug.

Orchard fruit insects.—Five and 8 per cent solutions of pine tar oils were found by the Maryland station to kill the woolly aphis on apple trees and to repel ants. Solutions stronger than 8 per cent were injurious to the tree. Two applications per year of an 8 per cent solution gave the best control with minimum injury to the tree, but a repetition of this annually for three years caused a considerable amount of injury. At the Virginia station spraying small apple trees in May proved most effective for the control of woolly aphis passing from elms to apples. Materials tested for the control of apple aphids at the West Virginia station, including dormant strength lime-sulfur, nicotine sulfate, miscible oils, and combinations of these, did not differ much in effectiveness. At the Maine station the green apple aphis was found to have many hosts not previously noted, including 24 botanic families.

The apple leaf roller was shown by the New York State station to be very resistant to common spray materials, the benefits derived from oil sprays being small, considering the cost. The preblossom and calyx applications were most beneficial. Late applications of spray or dust, preferably about the last week in August, were found by the Pennsylvania station to be necessary for the control of the leaf roller.

Life history studies of the apple maggot at the New Hampshire station showed two full broods in the State. In transfer tests the one-brood strains taken from New York to Massachusetts remained one brood, and the two-brood strains taken from Massachusetts to New York remained two brood. Crosses of the one-brood and two-brood strains gave progeny with two broods. Surface treatment with tobacco dust and lime was successful in control, sprays not being so efficient. The disposal of all dropped fruit, especially early apples, is recommended.

The pear psylla was satisfactorily controlled at the New York State station by all dust preparations containing nicotine, provided a sufficient amount was applied per tree.

Experiments with the peach and prune borer at the Oregon station showed that paradichlorbenzene was not effective with the western borer, which works higher up in the tree than the eastern form. Naphthalene whitewash gave good results when used late in the fall to catch the adults, followed by calcium cyanide in the spring.

The camphor scale was found to be widely disseminated in citrus trees, by the Alabama station. To control them, dormant oil spray should be applied immediately after the fruit is gathered, followed by a second application some time before spring. Light applications of heavy oils have given better results than light oils heavily applied.

Small-fruit insects.—Treatments with nicotine, soap, and water gave excellent control of the blackberry psyllid at the New Jersey stations.

Life history studies of the raspberry fruit worm at the Connecticut State station showed that this insect reaches the adult beetle stage in the fall, and winters as an adult. At the New York State station the following insects were found to act as carriers of raspberry mosaic: *Aphis rubi* and *A. rubiphila*, and the grape and apple leafhoppers.

The currant aphis was found by the New York State station to be susceptible to nicotine sulfate and soap sprays of standard strengths, as well as to dusting with sulfur-lead arsenate mixtures containing 1 or 2 per cent of nicotine. Superfine tobacco dust was also efficient.

The strawberry weevil was shown by the Tennessee station to hibernate in the woods and new plantings to be about as badly infested as old ones. Where serious infestation occurred, early poisoning was necessary. It was found that true sexual differentiation in the strawberry root louse did not usually appear until late in the fall. Exposing infested strawberry plants to 7.5 hours' daylight, beginning February 23, resulted in the appearance of the sex stages of the insect by May 7, and eggs were laid by May 22. Ordinarily this does not occur until well into November. The strawberry crown borer was found to be wingless and to migrate very slowly, so that new plantings with runners can be safely made within 100 yards of old ones; and this, with rotation of crops, will reduce the injury to a negligible one.

The cranberry girdler, according to the New Jersey stations, can be destroyed by summer flooding. Shallow flooding on sunny days did no damage, but deep flooding on dark days was injurious. At the Washington station excellent control of the cranberry fireworm was secured by spraying with nicotine sulfate, 1 part to 400 parts of water. The cranberry weevil was controlled by winter flooding. Where this was not possible sodium cyanide, 1 ounce to 15 gallons of water, 1 gallon to the square foot, was effective.

Vegetable insects.—The Alabama station found that the Mexican bean beetle produces two full generations each year, the life cycle requiring a minimum of about 30 days aside from the period of hibernation, which is about 200 days. It is rapidly spreading northward. It attacks all varieties of bush and pole beans, but Lima beans are somewhat less rapidly infested. Cowpeas are readily attacked and destroyed in the absence of more common food plants. Dusting with a mixture of calcium arsenate, sulphur, and hydrated lime in the proportion 1:1:4 is recommended. There was less burning when there was no dew on the plants and it is recommended that the dusting be done at intervals of 1 week to 10 days throughout the growing season. The Kentucky station found this insect for the first time in the State in June, in the southern part, but it has since spread northward and westward. Dusting with arsenate of lime and hydrated lime gave effective control.

Life history studies of the cabbage root maggot, at the Pennsylvania station, showed a first and partial second and third broods in eastern Pennsylvania. Two important parasites were reared from pupæ. The approximate time for the first treatment with corrosive sublimate for maggots on early cabbage is normally during the last week in April. At the New York State station, either corrosive sublimate or tobacco dust controlled the maggots effectively.

The striped cucumber beetle was more effectively controlled by calcium arsenate and gypsum than by nicotine dust in experiments at the Indiana station. The Missouri station reports that an effective way of repelling the beetles in a small garden is to press two or three naphthalene balls into the soil around each vine.

For the onion maggot fly, a poison bait of molasses and yeast with sodium arsenite proved to be very effective at the New Jersey stations. The bait also attracted the seed-corn maggot fly.

The green pea aphis is reported by the Michigan station to have invaded the State and to attack not only peas but also alfalfa. It is held somewhat in check by natural parasites, which include ladybirds, two species of hymenopterous parasites, one a Lysiphlebus, and a fungus disease identified as *Empusa aphidis*. Observations at the Wisconsin station indicate that alsike clover, red clover, and alfalfa are usually the center of early infestation of the pea aphis in cultivated fields, and from these the aphis slowly spreads to adjoining pea fields early in June. A large number of natural enemies were noted, which may entirely control them.

Life history studies of the spinach aphis (*Myzus persicæ*) at the Pennsylvania station, showed that the average reproductive period in the insectary was 14.8 days, during which an average of 21.2 young were produced by each female. Nicotine sulfate, 40 per cent, at a dilution of 1:500, using soap as a spreader and activator, gave efficient control. Dusting experiments showed a higher cost than spraying, but the efficiency was about the same.

Efficient control of the squash vine borer was secured at the Massachusetts station with nicotine sulfate, 1:100, as a spray. It acted somewhat as an ovicide, but mostly as a larvicide. Four applications made one week apart during July, at the rate of 300 gallons to the acre for the four applications, are recommended.

Stored grain insects.—It was found at the New Jersey station that when finely ground clays were inclosed in the same chamber with common white beans, but kept from direct contact with them by absorbent cotton, the infestation of weevils was reduced. When the clay was mixed with shelled corn and wheat it protected these grains against later attacks by the Angoumois moth, and mixing with wheat already infested reduced the infestation. The clay appears to act mechanically and can be easily washed off. A mixture of chloropicrine and carbon tetrachloride for fumigating grain in elevators was found by the Minnesota station to combine the good qualities and largely to overcome the disadvantages of each.

Scale insects.—The most satisfactory control of the San José scale was secured at the New York State station with a lime-sulfur solution, 1:8, applied as a spray when the buds were opening. With incrusted conditions, however, the Indiana station failed to get effective results with either dry or liquid concentrated lime-sulfur. Miscible oils or lubricating oil emulsions, when applied as dormant sprays in the fall or before the leaves came out in the spring, gave 100 per cent control. Lubricating oil emulsion is recommended for average conditions, because of its lower cost. The Arkansas station found that a 2 per cent lubricating oil emulsion dormant spray controlled the scale and did not injure peach trees.

Winter spraying for the oyster-shell scale proved ineffective at the Indiana station, because the insect passes the winter in the egg state, but summer sprays applied soon after the young hatch were thoroughly efficient.

Aphids.—The Maine station found that the green aphid of the apple has a winter and a summer food plant but may pass both cycles on the apple, being the only aphid of the apple that can do this. By the transference of winged forms one or two generations were bred on a number of other plants. It was found that *Aphis gossypii* has a similar range, and it is suspected that the two may be the same. There were found to be structural differences of *A. pomi* on different host plants. It usually occurs as a yellow form on its summer food plants, but is sometimes green. *A. gossypii* was found on the cucumber in one locality.

The length of day was shown by the Tennessee station to be an important factor influencing the early or late production of migrating forms of aphids. The primary host of the woolly aphis was found to be the elm in Tennessee as it is in Maine. The stem mothers hatched on the elm as early as the latter part of February and settled down at the base of a bud. The continued sucking caused the bud to swell and form a rosette in which vast numbers of lice were produced. The first winged forms or spring migrants developed the first week in May. As many as 10 to 12 generations were produced on the apple and by September the fall migrants made their appearance and continued to appear as late as December 1.

A variable temperature was shown by the West Virginia station to produce a greater growth in aphids than a constant one furnishing the same amount of heat.

Several new species of aphids affecting conifers were found at the Colorado station, some of these being of economic importance. Some forms were heavily parasitized.

Grasshoppers and crickets.—The fatal high and low temperatures for grasshoppers were found by the Minnesota station to be 52 to 54° C. and —10 to —12° C. High humidity apparently lowered the fatal high temperature.

Broadcasting poison bait for the control of crickets was found by the South Dakota station to be most effective if done in the late afternoon, as the feeding time of the insect is from 4 to 6 p. m. Addition of amyl acetate to the bait was of no advantage. Two parasites were found which were capable of destroying 50 per cent of the eggs. Cultivation was also an effective means of destroying the eggs.

Mosquitoes.—Observations made at the New Jersey stations showed temperature to be the governing factor in the activity of the mosquito. It decreased below 60° F. and stopped at 50°. Above 60° it increased two or threefold for each 10° increase up to an optimum of 80° and then decreased to 100°, when it stopped. Activity increased with humidity below 75 per cent, was constant from 75 to 85 per cent, and decreased at from 85 to 95 per cent. High temperature and low humidity increased the attraction to human beings, but this was overcome by high humidity and precipitation.

The chinch bug.—Calcium cyanide was found by the Missouri station to be efficient in preventing chinch-bug migration. The most effective way of using it was to plow a deep furrow between the corn and wheat, throwing the dirt towards the corn, and at the bottom of the furrow placing a line of calcium cyanide flakes, 1 pound to every 60 feet, preferably in the early part of the afternoon. It was found necessary to renew the application practically every day and in some cases to maintain the barrier for about 10 days. Dusting with calcium cyanide in the field before the bugs began to eat gave good control. At the South Dakota station there was found to be one complete and one partial generation of this insect in the State annually, only the adults and a few nymphs of the partial second generation surviving the winter. Natural enemies controlled to some extent.

Leafhoppers.—In the leafhoppers causing curly leaf of sugar beets, the California station found six instars when temperatures were high. In the cultivated districts of the San José Valley there were found four broods from April to October and a winter brood in the foothills. In the Salinas Valley three broods were found and at Berkeley two. No evidence was found that curly leaf is transmitted by the mouth parts or by external mechanical carriers. The minimum incubation period in sugar beets with two or four leaves was two days, the period varying with the size of the beet, the older the beet the longer the period. The causative agent traveled from the leaf through the blade into the beet, progressing 7 inches in a half hour. The inner leaves showed symptoms first. The disease was not transmitted from beet to beet through the soil, but only by the hopper, and no other insect was found that could transmit it. Thirteen weeds have been found which harbor the disease.

Cutworms.—Cutworms were controlled by the New Mexico station by the use of London purple. Tests at the Montana station showed early spring plowing to be of value in controlling the pale western cutworm. At the North Dakota station the most serious injury from this insect was in case of crops following small grain, especially wheat. Eggs of the insect were found commonly in hoof tracks in such fields. Little or no damage followed cultivated crops, as corn and potatoes, or grain crops such as rye, late flax, or late sown millet. A field with an unbroken crust, without wheel or hoof tracks, in early September, was likely to be free from infection and damage the following year.

Miscellaneous.—Wireworms were found by the New Jersey stations to eat large quantities of arsenic without injury, and they were also not injured by eating grains of corn treated with acids, alkalis, and other poisonous organic and inorganic materials. They were, however, easily killed with carbon bisulfide gas.

The best control of the black fly was secured by the New Hampshire station by treating the streams where they occur with an oil emulsion. They were found to be capable of flight for some distance. Three species were found in the State.

The flower thrips, according to the Florida station, attacks practically all truck crops that bloom, as well as many wild plants. The Pee Dee variety of Spanish peanuts was especially subject to attack, particularly on the leaves. Satsuma oranges were severely infested. Dusting with a mixture of tobacco extract and dry lime-sulfur gave good control.

A nematode-resistant bunch variety of velvet beans is reported by the Florida station. By growing this crop for a single season the number of nematodes was reduced in truck crop

soils as much as is usually the case where resistant crops are grown for two or three years in succession.

In a study of millipede control at the Pennsylvania station, soil treatment for a foot along the backboard of fall-seeded coldframes protected the entire bed from losses in case of lettuce and carrots. Either sodium cyanide solution sprinkled over the soil 10 days before seeding at the rate of 150 pounds of cyanide per acre, or nicotine sulphate in water, 1 : 500, one day before seeding, is recommended. Favorable results were also obtained with a nicotine sulfate dust in a kaolin carrier at a rate of 2 per cent actual nicotine scattered in the open row at the time the seed was drilled.

Good control of red spiders was secured at the Pennsylvania station with all liquid forms of sulfur, but dusts gave poor or little control. Commercial brands of miscible oils in the dormant or delayed dormant period gave from 60 to 80 per cent kill of red-spider eggs. Lime-sulfur gave from 12 to 20 per cent kill.

Insecticides.—Gypsum was found by the Iowa station to be a good addition to dusts for the melon aphis and striped cucumber beetle, both of which were found to be carriers of mosaic and wilt.

Studies of spreaders and adhesives at the New Jersey stations showed one of the best and cheapest to be flour, with a 12.5 to 16 per cent gluten content, mixed with lead arsenate at such a rate as to give the mixture a 3 per cent gluten content. Gas evolution from nicotine dust was shown to occur mostly in the first three hours and was practically over in nine hours. There was little evolution of gas below 50° F.

The incorporation of spreaders with common arsenicals exerted no appreciable influence, favorable or otherwise, on their killing properties or rate of action, in experiments at the New York State station. Attempts to grow tobacco with a high nicotine content, for insecticidal purposes, showed that fertilizer treatments had little effect. Superfine tobacco dust, applied in lime-sulfur solution, gave satisfactory control of red bugs and the rosy aphis.

The efficiency of nicotine sulfate was found by the California station to be increased from 20 to 30 per cent by the addition of sufficient alkali to neutralize the combining acids. Tests with calcium cyanide dust for scale insects showed that if this was finely divided it gave off gas quickly and freely and did not injure the foliage unless rains came, when the leaves dropped. Low temperatures seemed to harden some insects or make the gas ineffective.

Pure soaps (sodium stearate or oleate) were found by the Montana station to dissolve lead from both mono- and diplumbic arsenate, the latter being more soluble than the former. The solvent action of the stearate was greater than that of the oleate. There appears to be little danger of burning foliage if only oleate soap is used.

Bees.—The Minnesota station found that bees can regulate the body temperature within limits. The average temperature of the bee's body was 4.7° C. above that of the surrounding air when this was 5.5°. It was the same as the air temperature when this was from 35° to 40° and was lower when the air temperature was 52° or above, if not exposed to the high temperature too long a time. The fatal maximum body temperature was found to be 46° to 48°. The freezing point was —1° C.

Colonies wintered without packing at the Wisconsin station required 31 pounds of stores from November 26 to April 12, compared with 9.75 pounds for colonies wintered in a heavy packing case. A colony exposed to 57° F. formed a compact cluster and maintained the temperature within it by muscular action, the warmest part of the cluster varying from 70° to 90°. The colder the outside temperature the higher the temperature maintained within the cluster. A study of the variation in the size and shape of queen cells at the Texas station showed that unusually small cells did not contain enough food to last the young queens to emergence and they were small and inferior. It was found that unusually large cells produced relatively larger queens.

FOODS AND HUMAN NUTRITION

Studies with rats, at the Illinois station, on an 8 to 10 per cent plane showed that the biologic value (which is the ratio of the total absorbed nitrogen to the nitrogen retained in the body) was highest with veal, being 85, and lowest with tankage, 33. Milk was very close to veal, with 83, wheat averaged 70, potatoes 63, and navy beans 38. With animals on a 5 per cent plane, the biologic values were veal 97, milk 94, potatoes 39, and navy beans 29.

To test the popular belief that a high protein diet is a renal irritant,

rats were fed on such a diet at the Connecticut State station, with a suitable supply of vitamins A and B and inorganic salts. It was noted that the kidneys were hypertrophied, but this was not of an inflammatory nature and was not accompanied by hypertrophy of the heart. The animals grew from 60 to 260 grams in weight, with but little subcutaneous fat and the skin was adherent.

At the California station rats receiving strawberry juice with a non-vitamin C basal ration, did well and reproduced, but did not thrive well with loganberry juice. Studies of raisins, dried raisin seed, and raisin-seed oil, at the Pennsylvania station, showed these materials to contain little if any vitamin A but vitamin B was present to an appreciable extent. Dried raisin seeds were not so rich in this as were raisins. It was not possible to demonstrate the presence of vitamin C in these materials.

Investigations on canned peas, at the Wisconsin station, showed them to be inferior in vitamin content to fresh peas which were cooked by steam and subsequently dried, although they were not entirely valueless as a source of vitamin B.

A close relation was found, by the New York State station, to exist between the moisture content and popping quality of pop corn. As the moisture content increased, the yield of popped corn increased to a maximum and then declined, as measured by volume. Corn stored outside popped better than that stored inside of storage rooms, on account of the moisture. Pop corn that did not germinate was still good to pop.

Studies on flour, at the Minnesota station, showed that no extracellular proteases are contributed to a dough in consequence of the inclusion of soured baker's yeast, and cleavage of the gluten is not affected by yeast to an extent that renders such changes a contributing factor in dough fermentation. Alkaline sodium phosphate produced more unfavorable effects upon the dough, due to alkaline residual salts, than did acid ingredients commonly used in baking powders and self-raising flours.

In studies of the nutritive value of milk, at the Vermont station, pigs were fed from 2 days old to weaning time, with a normal milk containing 3½ per cent protein, to which powdered protein was added, up to 10 per cent. The results showed that an addition of 2 per cent was the economical limit. Similarly, pigs were fed with milk containing 2, 3½, and 5 per cent of fat. Measured by the composition of the body at weaning time and the amount of gain, 2 per cent milk was the most economical. Data obtained at the Pennsylvania station indicated that pasteurization has no appreciable effect on the chemical and physical properties of the various milk constituents, and no nutritive difference was noted when fed to rats. Studies at the Minnesota station show that human milk is quite as adequate as cow's milk, as a source of vitamin A, for experimental animals, but is not adequate as a source of vitamin B in amounts which give good results with cow's milk.

Investigations on the preservation of eggs, at the Montana station, showed that at least two kinds of molds and a dozen species of bacteria frequently take part in egg spoilage. Of the various methods compared, immersion in water glass diluted 1 to 15, gave the best results and had an antiseptic action. Whatever preservative is used a relatively low temperature is best to preserve the natural flavor. The cost was a little less than 2 cents a dozen for materials and labor.

ANIMAL NUTRITION

Vitamins.—Experiments at the Iowa station with rats, rabbits, guinea pigs, and pigeons showed that vitamins in the ration are important in maintaining natural resistance to bacterial infection. Rats with a deficiency of vitamin B showed a marked susceptibility to anthrax and pneumonia. Vitamin deficient rats were also more susceptible to diphtheria toxin than normal animals. A marked drop in body temperature occurred, followed by subnormal phagocytic activity. Poor, weathered alfalfa hay was found to be poor in vitamins. Ordinary feeding rations were found to be very likely low in vitamins. The requirement for vitamin B appeared to be greater in chicks than in mammals. It was found at the Kansas station that chicks did well for a while without vitamin C, but if vitamin B was omitted the chicks developed beriberi. Cows responded to vitamins in the same manner as other animals, and although they got along for some time without vitamin C they ultimately succumbed. Bacteria producing vitamin B was found to occur in the paunch of the cow. Lack of vitamin A caused nervous disorders in pigs, with paralysis and poor vision, leading to blindness but no disorder of the eyeball, the results resembling blind staggers in horses. Hogs got along for a con-

siderable time on a limited amount of vitamin C (or green feed), but brood sows did not do so well. Pigs fed on a basal ration with no vitamin either died or were abnormal, but were cured with cod-liver oil.

In a comparison of milk and its preparations, at the Missouri station, unpasteurized whole milk gave the most uniform and most nearly normal growth of rats, while whole milk powder gave a very comparable growth curve. Skim milk gave practically the same rate of growth as whole milk for two months, when the rats became more susceptible to colds and reproduced but little. Evaporated milk gave low growth and low production, but the rats were healthy. Growth on filled milk was very low, the curve was nearly flat after 10 days, and there was no reproduction. Tests indicated that if vitamin B was deficient high protein (casein) afforded some protection.

With chicks fed a ration deficient in vitamin A, the Ohio station found a marked response with dried buttermilk, which seemed to supply something deficient in meat scraps. White clover gave as good results as butterfat. Cod-liver oil was not effective with a synthetic ration, but with normal food the results were good. With a synthetic ration the average weight of chicks receiving cod-liver oil was less than those receiving butterfat, but the percentage of lime in the bones was higher. The most practicable sources of vitamins required for the growth of chicks appeared to be green clover, alfalfa, cabbage, and grasses. Consistent results were obtained with rats, showing that these animals do not have the capacity of storing vitamin B.

The distribution of the antirachitic factor was found by the Wisconsin station to be very different from that of other vitamins. Attempts to extract this vitamin from hays by alcohol failed. Ordinary white light, as well as the light from a mercury vapor lamp, was found to supplement a ration low in antirachitic vitamin, producing an effect similar to that obtained when it is present. It seems possible that animal life is dependent for its mineral regulation more upon sunlight than upon food material. Rats were found to store fat-soluble vitamin in large amounts for future use, the liver being apparently an important center of such storage, the amount stored varying with the amount fed in the ration. Millets were found to be uniformly rich in fat-soluble vitamins, which bore no definite relation to the yellow pigment. Data were secured showing that cod-liver oil contains both vitamin A and antirachitic vitamin. Phosphorus in the blood appeared to be correlated with growth and may be an index of the need of antirachitic vitamin. Antirachitic vitamin was destroyed by fermentation, and germination appeared to activate the vitamin. This station also found the antirachitic vitamin of alfalfa hay to be destroyed by exposing it to the sunlight and weather, and assimilation of calcium in the body of animals receiving such hay was impeded. Although alfalfa hay cured in the ordinary manner was quite as high in lime content as that cured in the dark, its lime content was apparently completely unavailable. Hays dried in the sun but not exposed to the influence of moisture, as rain and dew, retained the antirachitic factor in greater abundance than those cured with exposure to all weather.

Preliminary studies at the Pennsylvania station indicated that vitamin B is not destroyed by any of the processes used in evaporating milk. Sweet cream butter, not overworked, was found to give the highest content of vitamin A.

Cooking cowpeas did not lower their vitamin value in experiments at the Arkansas station. The ground bean was rich in vitamin B but less so in vitamin A. The proteins were found to be very satisfactory, but the minerals were rather deficient. Tests with the whole mature plant showed that the proteins were not so good, vitamin B was very good, and vitamin A good, and the mineral matter was sufficient.

The vitamin B content of the entire egg yolk is not large, according to the Connecticut State station; and the whole egg is not exceptionally rich in vitamin B, as compared with many other foods. Experiments with rats showed that an average egg is equivalent to the vitamin B potency of about 150 cubic centimeters of cows' milk, or a quart of milk is about equivalent to six or seven whole eggs. Evidence points to the storage of vitamin in the body and not to its synthesis. Two lots of rats were fed, one with a normal diet and one with a diet deficient in water-soluble vitamin. Other rats were then fed on the livers of these. Those fed on the first lot responded quickly and did well, but those fed on the livers from the depleted lot did not. It was found that cod-liver oil, through which oxygen had been bubbled for a considerable

time while the fat was kept warm, lost its vitamin A potency and its capacity to cure ophthalmia, but the mere heating of a vitamin A-bearing product did not necessarily destroy its potency.

Experiments on the seasonal variation in the vitamin A and B content of milk, at the Minnesota station, showed that a milk rich in vitamin, particularly vitamin B, is not necessarily associated with a diet of pasture alone, although it is distinctly better in vitamin A. It is believed that cows on pasture should be fed a liberal grain ration in order to insure an optimum content of vitamin B in the milk. It was found that vitamin B in milk was not affected by either the spray or drum process of drying, but the vitamin A content of drum-dried milk seemed to more nearly approximate the original milk in this respect than did milk dried by the spray process. It was found necessary to heat milk to 180° F. for an hour in the presence of a stream of oxygen in order to destroy its antiscorbutic vitamin. The vitamin A content of butter showed a noticeable diminution when the butter was kept at a freezing temperature for nine months. Studies on the effect of vitamin B deficient diets on the growth and development of the organs of cockerels showed that the birds receiving such a diet suffered a decrease in size and weight of the organs in the following order: Testes, spleen, heart, liver, kidneys, pancreas, and thyroid, the testes being affected the most and the thyroid least. The animals increased in weight. A definite accelerating effect was noted, with vitamin B, on salivary amylase. Evidence was obtained that rats do well on diets free from carotinoids, confirming the conclusion that there is no chemical relation between carotin and vitamin.

Velvet beans were found by the Alabama station only slightly to benefit pigeons affected with polyneuritis from a polished rice feed; but, when fed the alcoholic extract of the beans, four out of six cases recovered. Rats did not thrive on any ration containing velvet beans. Velvet bean and pod meal was found by the Arkansas station to be rich in vitamin B, which, however, was mostly concentrated in the pod, while both the pod meal and beans were rich in vitamin A.

Chickens fed upon degerminated white corn developed leg weakness, which was cured by the addition of yeast, in experiments at the Indiana station.

Mineral nutrition.—A high degree of tolerance to acids in mineral metabolism without harmful effects was shown in experiments with swine at the Iowa station.

Green feeds helped calcium metabolism as lactation advanced, in experiments at the Ohio station, as a result of better digestion, and this appeared to be as much of a factor as the vitamins. Fineness of division appeared also to be a factor in assimilation. Goats fed colloidal phosphate stored calcium, but those receiving coarser phosphate did not.

A positive calcium and phosphorus balance was maintained in liberally milking cows, in experiments at the Wisconsin station, when dry alfalfa hay of good quality was used as the principal roughage, supplemented with corn silage and a grain ration. There was a greater storage of calcium when fresh green alfalfa was used. The results with hay depended upon its character as affected by curing. Negative calcium and phosphorus balances were obtained with rations of grains, corn, silage, and timothy hay. Substituting alfalfa hay or bone meal for the timothy hay did not restore the balance. With young rats, calcium lactate, carbonate, phosphate, silicate, and sulfate appeared to be equally assimilable. The larger the calcium intake the less the vitamin required for normal growth. Deficient calcium assimilation with abundant calcium intake was apparently not due to the form of the calcium but to deficiency of vitamin. Hay from a highly acid soil, the hay containing less than 0.5 per cent calcium oxid, inhibited reproduction. Cows fed rations containing plenty of protein but low in lime produced calves that were either dead at birth or so weak that they died shortly after. Cows fed a ration of timothy hay (containing only 0.73 per cent of calcium oxide), silage, and grain, compared with a lot receiving alfalfa hay, silage, and grain, were much slower in breeding and gave a rapid decrease in milk flow, and dried off earlier after being bred, indicating that a depletion of lime was probably taking place. There was apparently no difference in the effect of the type of calcium carrier used for the prevention of rickets, provided there was present an ample supply of antirachitic vitamin. Twenty cubic centimeters of cod-liver oil per week per animal was sufficient to protect against rickets. It was found that swine getting no dairy by-products, tankage, or green pasture were benefited by lime in the form of

steamed bone meal, wood ashes, ground limestone, or rock phosphate at the rate of 0.5 to 2 pounds per 100 pounds of grain or other concentrate. Lime appeared also to be needed when whey was used. Cows, sheep, and horses on forage from acid soils or on nonleguminous forage were benefited by lime at the rate of 3 to 4 pounds of the above mixture per 100 pounds of grain; and, even with legumes, bone meal or rock phosphate was used with advantage. Grains, wheat bran, and middlings being rich in phosphates did not require additions of this substance.

A wheat ration consisting of a constant amount of wheat, gluten, purified butterfat (vitamin A), calcium, and chlorine, with varying quantities of potassium, ranging from 0.03 to nearly 4 per cent, was fed to small animals at the Washington station. The rations containing the smaller quantities of potassium proved to be about sufficient for maintenance, whereas animals receiving larger proportions lost in weight and failed to reproduce. It appeared from experiments that potassium could not replace sodium, which is necessary whereas potassium is not. The amount of potassium in wheat is comparatively high. The variation of chlorine may be large in a wheat ration without greatly affecting growth and reproduction. A very small quantity of chlorine seems to promote growth and reproduction, and a large quantity does not seem to be detrimental. Neither wheat nor flour supplies a maintenance ration, but wheat can be made to by the addition of prepared butterfat, although still not adequate for growth and reproduction.

Velvet bean and pod meal was found by the Arkansas station to contain sufficient mineral salts for good growth, but the beans alone were deficient in minerals. All varieties of velvet beans were shown by the Alabama station to be low in ash and chlorine.

Larger amounts of manganese, copper, and zinc were found in the liver of animals than in other parts of the body, in studies at the Kentucky station. The copper content was higher in calves' liver than in that of more mature animals. Colostrum was found to be richer in manganese than milk produced later.

Protein.—The Nebraska station found that the skeleton was not influenced by increase of protein and an excess of protein tended to reduce the average daily gain in weight. A high protein ration was not found to be economical. The protein of velvet beans was found by the Arkansas station to be poor in amino acids and to give poor growth in pigs.

The proteins of corn meal and bran were found by the New York Cornell station to supplement each other and furnish a mixture of high quality. A combination of soybean oil meal and corn meal was found more efficient than corn meal alone.

Effect of sunlight.—At the Wisconsin station chickens fed a ration of white corn 60 parts, middlings 40 parts, salt 1 per cent, with skim milk to drink, died after four weeks unless kept in sunlight or given a small amount of raw egg (three eggs to 100 chicks). Feeding pork liver to hens produced better-hatching eggs and stronger chicks. Experiments with both poultry and calves, at the Kansas station, indicated that sunlight plays an important part in the development and metabolism.

Colostrum.—Calves fed pasteurized colostrum for the first three days and then put on cows' milk did as well as those on normal colostrum at the Missouri station. Of a group of 22 calves fed mixed milk from birth with no colostrum, 9 died and 13 were raised. White of egg in place of colostrum gave satisfactory results. Tests showed that guinea pigs do not need colostrum. Lambs were raised without colostrum, but pigs from which it was withheld died.

ANIMAL PRODUCTION

GENERAL

Influence of sires.—A study of blood lines of various classes of farm animals at the Virginia station indicated that breeds have been largely shaped and molded by the sires and that the future development of any breed depends to a very great extent upon its great sires.

Surface area of cattle.—An exact formula has been developed by the Missouri station for calculating the surface area of cattle, with an error of ±5.5 per cent. This is $S=L^{.6}\times W^{.4}\times K$, where L is the length of the body in centimeters, the distance from the point of the withers to the end of the ischium or pin bone, W is the weight in kilograms, K a constant 217, and S the area in square centimeters.

Effect of arsenic on fecundity.—In experiments with rabbits at the Illinois station, with double simultaneous matings of different colored males to a single female, one male having re-

ceived Fowler's solution, the other not, 96 young were obtained, only 15 of which came from the treated and 81 from the untreated male. This seems to indicate that arsenic either decreases fertility or so weakens the spermatozoa that it decreases competition with sperm from untreated males.

BEEF CATTLE

Brahman-Hereford crosses.—Brahman-Hereford hybrids, at the Texas station, showed very little difference in susceptibility to the ox warble, but were apparently considerably less susceptible to horn flies. The first crosses were heavier than the Herefords.

Feeding.—In comparing oat straw, mixed hay, and corn stover, as a supplementary roughage to corn silage and cottonseed meal, at the Pennsylvania station, corn stover ranked first, oat straw second, and mixed hay third, from the standpoint of cheapness of ration, but mixed hay ranked first in maintaining the weight of the cows. Some of the cows getting oat straw or corn stover failed to breed regularly.

In experiments at the Montana station, younger cattle made more economical gains and slightly higher daily gains than older ones. The lighter cattle were in more favor with buyers.

In experiments at the Nebraska station with four groups of steers ranging in age from calves to 3-year-olds, the calves consumed much less feed than the older cattle and made much more economical gains. They likewise gained consistently throughout the period, whereas the older cattle gained rapidly at first and very slowly toward the close of the period. Heifer calves gained more slowly than steers and sold for a lower price.

Steers kept for a whole winter in a state of undernutrition at the New Hampshire station showed a capacity, with equal opportunity, to attain the same market finish as those wintered under normal conditions.

More profit was obtained at the Tennessee station from finishing winter-fed steers on grass than finishing during the winter period.

Steers fed on normal silage, at the Michigan station, made cheaper and larger daily gains, took on more finish, and sold at a higher price per pound than did steers fed on stover silage and corn.

Sunflower silage did not prove to be an economical winter feed for range calves at the Wyoming station. Native hay alone produced about one-third of a pound of gain per day and proved a sufficient winter feed for weanling calves. The addition of cottonseed meal, however, was a decided advantage.

Silage made from immature sunflowers was more palatable and gave better gains than that from more mature plants, at the Colorado station.

Experiments with corn, sunflower, sweet clover, sweet clover and oat straw, and millet silages, with 2-year-old steers, at the North Dakota station, showed that sweet-clover silage alone was more nutritious than sweet-clover and oat-straw silage, but was inferior to corn silage. Millet silage was less palatable than corn silage, as was sunflower silage, the latter being also distinctly inferior to it in nutritive value, but was superior to sweet-clover silage. Best sunflower silage was obtained from plants about 85 per cent in bloom.

SHEEP

Breeding.—Range ewes were bred to an average range buck, a crossbred buck, and a purebred buck, at the Nevada station. At the end of 180 days the lambs from the purebred sire weighed 12 pounds more than those from the range bucks, and 7 pounds more than those from the crossbreds, and the better-bred lambs gave a considerable increase in wool.

Short ears in ewes has been found by the New Hampshire station to be a Mendelian character, and the station has bred sheep in which this character is dominant.

Feeding.—Experiments at the Nevada station indicated that old range ewes can be brought through the winter on sunflower silage in such condition that they can lamb and mother their offspring. Sunflower silage has given as good results as corn silage for this purpose.

Investigations on lamb production at the Nevada station emphasized the importance of feeding ewes during the lambing period and putting lambs and ewes on the range in the best possible condition in order to bring the lambs through the summer in good condition. Lambs from better quality of bucks showed earlier maturity, better conformation, and improved wool. The advisability of carrying range lambs for a short feeding period on any available pasturage prior to shipment and the importance of alfalfa stubble pasture in this connection were also emphasized.

At the Iowa station shelled corn gave more satisfactory results than oats and barley fed with corn silage

linseed-oil meal, clover hay, hominy feed, or gluten feed for fattening lambs. Beet molasses gave better results than cane molasses, but neither was equal to a corn ration.

In fattening lambs at the Oklahoma station unground kafir equaled ground. At the Kansas station whole kafir compared favorably with shelled corn. Grinding did not warrant the expense and threshing was of little advantage.

Almost the same gains were obtained at the Illinois station from a ration of shelled corn and alfalfa hay as from one of shelled corn and soybean hay, but it required 14 pounds more of corn and 93 pounds more of soybean hay than of shelled corn and alfalfa hay to produce 100 pounds gain. Lambs that received soybean straw as roughage required much more concentrates as well as roughage to produce 100 pounds gain than lambs fed alfalfa or soybean hay as roughage. Of the supplements used, ground soybeans were the least satisfactory. Both soybean-oil meal and linseed-oil meal produced slightly better gains than whole or ground soybeans.

Wool.—The New Hampshire station found that figures on tension and other characters of wool are only of value when taken under definite moisture and temperature conditions; length and diameter of fiber are more reliable.

The opinion generally held that the shoulder wool is always the finest on the sheep was found by the Wyoming station not to be true in all cases, especially with Hampshires, in which the middle of the side wool is slightly finer than the shoulder wool.

The average shrinkage on scouring was found by the Texas station to be 60.14 per cent with Rambouillet wool, 48.72 per cent with Corriedales, and 15.3 per cent for mohair. Shearing twice a year was found to be less profitable, when practiced over a series of years, than shearing once a year.

Goats.—Half-blood Toggenburg does, at the New Mexico station, produced 73.2 per cent more milk in their first lactation period than their native dams, and three-fourths bloods showed an average increase of 86.4 per cent over their granddams.

SWINE

Age and nutrition as factors in breeding.—Experimenting with sows, at the Missouri station, on three planes of nutrition from weaning time, those on a high plane came in heat first and those on a low plane last. The effect of the plane of the mother on the offspring was evident only up to the time of weaning and was due, evidently, to the fact that the low-plane mothers could not nourish their offspring as well as the high-plane mothers. Breeding as soon as pigs came in heat the first time has given no injurious effect on the progeny through 13 generations. Young pregnant sows continued to grow normally, gestation having no retarding effect; but, from the birth of the pigs, growth of the sow stopped for one or two months, becoming about normal as soon as the pigs were weaned. The younger-bred sows required from 12 to 15 months longer to reach normal mature size, and the offspring of very young sows required about 10 days more to reach 250 pounds. The type of hog was not injured by early breeding.

Market type.—In a comparison of compact, intermediate, and rangy types of Poland-China hogs, at the Illinois station, the intermediate type produced 3.6 per cent more rapid gains than the compact type, and 15 per cent more than the rangy type. The compact type required 3 per cent more feed and the rangy type 8 per cent more than the intermediate type to produce 100 pounds of gain. The carcasses of the compact type contained 6 per cent more fat and those of the rangy type 6 per cent less fat, than those of the intermediate type, and this type dressed better.

Feeding.—In a comparison of alfalfa and grain for brood sows, at the Delaware station, the alfalfa lot made the largest and the cheapest gains.

Excellent results were obtained with corn as the only grain for brood sows at the Wisconsin station, if this was properly supplemented and was strictly limited to the amount needed to keep the sows in a thrifty condition without becoming too fat. A ration of legume hay and grain was satisfactory. The addition of roots to the ration did not result in larger or more thrifty pigs, and was uneconomical under Corn-Belt conditions. No advantage resulted from adding a mineral supplement, such as steamed bone meal or ground limestone, to an efficient and well-balanced ration which included tankage.

Young pigs put on full feed after being fed for long periods on a maintenance ration were found by the Utah station to grow more rapidly and require less feed for a given increase than similar pigs put on the same feeds at once.

About 2.6 per cent less kafir was required per 100 pounds gain, in experiments at the Kansas station, when fed in the head than when threshed and fed whole; about 18.5 per cent less was required when fed threshed and ground than when fed in the head. Ground kafir was 35 per cent more effective than unground, in experiments at the Oklahoma station, the ground kafir more nearly equaling ground corn than did ground darso.

In a comparison of milo versus corn chops, with wheat straw, at the Texas station, pound for pound, milo was equal to corn; but when self-fed the pigs ate more corn and gained more.

Pigs 100 days old fed uncooked garbage from the university commons with barley, at the Wyoming station, made economical gains. Feeding potatoes alone gave poor results, better results being obtained when alfalfa, barley, and a mineral mixture were added.

In experiments at the North Carolina station, sweet potatoes were worth 34 cents per bushel, when fed alone, and 25 cents per bushel when fed with 2 per cent of corn. The pigs sold at a premium because of their excellent quality.

Soybeans planted in corn to be hogged down did not completely take the place of tankage in experiments at the Missouri station. Hogs on corn plus soybeans alone made more rapid gains and slightly more pork per acre than on corn alone; but since the amount of feed produced per acre with corn plus soybeans was usually no larger or even less than with corn alone, there was little more pork production per acre. Feeding tankage in a self-feeder to hogs on corn alone or on corn plus soybeans materially increased the rate and economy of gain.

Efforts to find a home-grown substitute for tankage at the Indiana station showed that soybeans may serve this purpose. When first fed they did not give as good gains as tankage; but it was found that by adding a mineral supplement they gave even better gains than corn and tankage, and the cost of gain was less. Supplementing corn with soybeans did not produce soft pork. The mineral mixture used was 1 part salt and 10 parts each of acid phosphate and wood ashes. There was less response with young pigs than with older ones.

A comparison of tankage, fish meal, peanut meal, and soybean meal at the Delaware station showed a decided advantage for the animal proteins in gains made, cost of gains, and finish.

Linseed meal or wheat middlings, as the only supplement to corn or barley for pigs not on pasture, gave poor results at the Wisconsin station, but better results with those on good pasture. Excellent results were secured with a mixture of equal parts of tankage and linseed meal when fed as a supplement to corn for pigs on good pasture, but this was not satisfactory for pigs on dry lot. For winter feeding a mixture of 50 pounds tankage, 25 pounds linseed meal, and 25 pounds chopped alfalfa proved very effective.

Ground barley, dry or soaked 12 hours, whole barley soaked 24 hours, and dry whole barley were compared at the Montana station with the result that grinding saved about 6 per cent of the feed and the gains were faster than with whole barley. It required 12 and 20 per cent more time, respectively, to finish the pigs fed the whole soaked barley and the whole dry barley than those fed ground barley.

Brood sows fed continuously on velvet beans, at the Alabama station, were deficient in milk production, and the pigs produced were below normal in weight and did not survive. Pigs fed rations rich in velvet beans for 180 days had bones of low specific gravity. The rations were not so efficient as those containing corn, shorts, and tankage. Older pigs ate and digested the beans more readily than younger ones. The iodine number of the fat of pigs fed velvet beans indicated soft pork. Velvet beans variously prepared and fed in varying quantities with corn and tankage did not give economical gains at the South Carolina station. The feed did not appear to be palatable. There was some indication that mature pigs made better use of the beans than younger ones. Pregnant sows fed velvet beans produced weak pigs which, however, survived.

The amount of high-priced tankage may be materially reduced, according to the Iowa station, by the use of good green pasture, such as alfalfa, clover, rape, and various other crops, the results being especially good with alfalfa. Tankage gave good results as a supplement to corn and alfalfa pasture at the Kansas station.

Commercial buttermilk feeds were not economical as compared with tankage or creamery buttermilk for pigs from 75 to 175 pounds weight, in experiments at the Minnesota station.

The Kentucky station found that spoiled buttermilk, even when putrid, did not injure pigs.

Pigs were stunted, in experiments at the Michigan station, by feeding yellow corn alone up to 5 months of age, and then divided into two lots weighing practically the same, one lot being then fed yellow corn and skim milk and the other yellow corn and a mineral mixture. At 12 months of age the pigs receiving the corn and mineral mixture weighed 76 pounds, while those receiving corn and skim milk weighed 335 pounds. At the Nebraska station, yellow corn and tankage gave better results than either white or mixed corn and tankage. The Iowa station found yellow corn better for growing and white corn better for fattening pigs.

Pigs on bluegrass pasture with a supplemental feed containing 20 per cent of tankage were supplied with various mineral supplement mixtures, in experiments at the Iowa station. The lot receiving no mineral supplements gained less and more slowly and required more feed per 100 pounds of gain than those receiving some form of mineral supplement. Similar results were obtained with pigs fed in the dry lot. The addition of powdered sulphur to a basal mineral mixture composed of salt, bone meal, ground limestone, wood ashes, and potassium iodide proved to be advantageous in that the gains were slightly increased and the feed requirement lessened. The Wisconsin station found that commercial mineral mixtures contain many useless ingredients, and advises the use of mixtures of bone meal, wood ashes, and ground phosphate. Mineral supplements were apparently not necessary for pigs on tankage or pasture. When marble dust, salt, and charcoal in equal amounts by weight were added to a ration of 2 parts corn and 1 part peanut meal, at the Alabama station, there was an increase in gain and in economy of feed, and the bones of the animals receiving the supplement were stronger than those not receiving it.

The age of pigs is an important factor in the production of soft pork, according to the Mississippi station, older pigs utilizing feed to much better advantage than young ones. Tests at the Georgia station showed that an excess of butterfat in the ration did not produce a soft body fat. When butterfat was fed for three months at the rate of 0.75 pound per day, the pork fat was firm and hard; the same quantity of peanut oil in the basal ration produced a somewhat softer fat. Hogging down corn with soybeans planted in the rows did not produce soft pork at the Kentucky station. At the Texas station, 140-pound pigs fed for 60 days on a ration containing 50 and 60 per cent of rice polish, with corn and tankage, did not produce carcasses sufficiently soft to require dockage. Several hogs receiving rice bran and one receiving rice polish were classed as slightly soft but were not docked. Rations containing 50 per cent of bran or polish produced greater gains and required less feed per unit of gain than those containing 60 per cent. Rice polish produced more gain per pound of feed than corn. Rice bran was more efficient in the fattening than in the growing ration. Paddy rice fed with tankage gave good results at the California station, the hulls giving no trouble. Rice bran and polish also gave good results, but the bran made the hogs rather soft while the polish caused them to scour.

Self-fed pigs, at the Texas station, reached a market weight at an earlier age than those hand fed. Self-feeding produced larger daily gains than hand feeding, but the amount of feed required to produce 100 pounds of gain was less in the case of the hand-fed lot.

POULTRY

Breeding.—As a result of very close inbreeding, at the Connecticut Storrs station, the hatchability of fertile eggs dropped nearly to zero in the third generation. The mortality of the 3-weeks old chicks increased from 3.6 to 24.7 per cent. The growth fell off rapidly in succeeding generations. The date of first egg (sexual maturity) increased from 220 days to 300 days in the sixth generation, and the average number of winter eggs fell off rapidly from 30 to 4. The egg size, however, did not go down and it is doubtful if the mature body size and weight did, for although inbreds were lighter at first they caught up in about two years, the size being measured by the bones.

By using males from pens having the highest percentage of fertility, the Montana station found an increase in hatchability in three years of 24.2 per cent. The amount of artificial light did not affect the hatchability of the eggs.

Organ transplantation.—Experiments at the Maine station showed that the presence of sperm or the antibodies to sperm did not apparently alter the ovaries or their functioning.

Egg production.—Eight years' data at the Indiana station show that pullets

maturing at 6 to 7½ months made higher average first-year records than those maturing earlier or later. Birds which laid before 8 months of age had a higher winter production than those beginning to lay later. Persistence of laying, or lateness in fall and winter, indicates a high producer. The number of eggs laid during the month of highest production is closely correlated with production.

The West Virginia station found that the younger the pullets when they began to lay the smaller were the first eggs. There was no correlation between early maturity and mean egg weight for the pullet year. The characteristics of the first four eggs laid in the pullet year tended to persist, especially the weight. Increased production was not necessarily at the expense of size of egg, but the more eggs laid in a particular period the smaller they tended to become. The mortality of progeny of fowls fed heavily for winter production was considererably greater than that for the progeny of those fed scantily during that time.

The North Dakota station found great variation in size of the first egg laid by individual pullets, from 1⅓ to 2 ounces, and that some individuals settle down to a normal-sized egg much younger than others, some never reaching a standard-sized egg.

The later the molting the higher the egg production, according to the Missouri station, except in the case of hens molting in October, which did not come back as well as those molting a month earlier. Hens molting after November 1 gave a much higher total egg production for two years than those molting before that date. A definite correlation between the date of starting molt and yearly production was found by the Iowa station, the high producers starting from October to December, the low producers any time after the first of June. The speed of molt also appeared to be correlated, high producers requiring about 100 days and low producers from 180 to 200 days. The wing molt appeared to be closely correlated with production. High producers laid more eggs while molting than low producers. Apparently the best layers tend to give a somewhat poorer hatching percentage than the poorer layers. With Leghorns, about the first of April was found to be the most advantageous date of hatching in relation to future egg production.

Experiments with a commercial yeast product, at the Pennsylvania station, indicated that pullets and hens not forced for egg production, and under conditions employing a good ration with adequate yards and runs, do not appear to need an additional amount of vitamin B supplied in the form of a yeast product to maintain their egg production and body weight. Hens and pullets ate more food as a rule and their body weights were somewhat more uniform when the yeast product was fed. It did not appear to be profitable to feed the yeast product except when pullets were forced to undergo a longer feeding and exercising period by the use of artificial light, under which conditions White Leghorn pullets were found to develop better and lay more and larger and heavier eggs.

Incubation.—The West Virginia station found the amount of carbon dioxide given off to be small until the middle of incubation, when increasingly large quantities of oxygen were taken in. The increase from the nineteenth to the twentieth day was practically equal to the total carbon dioxide given off during the first eight days and the increase from the twentieth to the twenty-first day was roughly equal to all that given off during the first half of the hatch. At the Missouri station, one lot of eggs held at 99° F. hatched. Below that, although there was considerable growth of embryo down to 94° F., none hatched.

Hatchability.—Normal-shaped eggs were found by the Masschusetts station to hatch best. The position of the embryo in the egg was not responsible for failure to hatch.

Deficiencies in either vitamin A or B in the ration were found by the Kansas station to result in extremely low hatching percentages, as did also the feeding of rations which did not include any green feed. The number of in-shell deaths was found to be greatest on the nineteenth day and 65 per cent occurred in the last week. No correlation was found between the weight of egg and in-shell deaths by the Connecticut Storrs station. The inheritance of in-shell deaths was found to be a simple character, as a rule, but in one case it was linked with a color character.

Effect of light.—The Nebraska station observed that chicks on a standard ration, which were exposed for an average of less than one hour daily to direct, unfiltered sunlight, developed normally, whereas chicks exposed to sunlight which had passed through common window glass devel-

›ed rachitic symptoms. It is be-eved that the ultra-violet rays, which re filtered out when sunlight passes rough window glass, are the active gents which influence calcium and osphorus assimilation.

The increased winter production, ith light, was much more pronounced ith yearling hens, in experiments at e Kentucky station. Hens under ght average 18 more eggs per bird uring the four winter months than ose without light. At the New Mex-o station eggs produced under elec-ic light did not give as high incuba-on, there being more dead-germ eggs.

Feeding.—The West Virginia sta-on found that poorly fed chicks, hich are stunted, never attain nor-al live weight even when afterwards d normal rations. Egg production r the first season was reduced and e chicks were slower in reaching exual maturity. At the Wisconsin ation, chicks hatched from eggs from ens fed on a white corn and pork ver ration, as compared with those atched from eggs from hens fed yel-w corn and pork liver, died soon fter hatching., and the hatchability as very low, indicating the necessity f vitamin-rich feed in the poultry ation. At the Kansas station, male icks on deficient rations died sooner an females. Other factors besides od, such as sunlight and exercise, ter into the problem.

In a comparison of tankage, cotton-eed meal, and a mixture of the two, t the Texas station, the cottonseed eal lot gave about 10 per cent more ggs. In a similar test with meat rap, the cottonseed meal also showed p well.

The addition of sour skim milk, emisolid buttermilk, or meat scrap to ration consisting of a grain mixture nd a mash of ground grains and heat by-products more than doubled e winter egg production, in experi-ents at the Kentucky station. Tests t the Iowa station emphasized the alue of fresh buttermilk for laying ens.

Twenty per cent of meat meal in ations was replaced by fish meal ithout causing a fishy taste in the ggs, in experiments at the North arolina station.

Grains being deficient in calcium, odium, chlorine, and phosphorus, the ddition of mineral matter to the rain or mash ration for ducks was ollowed by very favorable results in xperiments at the North Carolina ation.

Culling.—Trap nesting in July and August was found by the Iowa station to be best for accurate culling of the breeding flock.

Passage of food through the fowl.—The North Carolina station found that food passes most rapidly through the intestinal tract of laying and growing fowls, requiring on an average 3 hours 52 minutes for growing fowls, 3 hours 46 minutes for laying hens, 8 hours for adult hens, not laying, and 11 hours 44 minutes for broody hens.

DAIRYING

Breeding.—Close inbreeding for several years, at the Ohio station, starting with good producers, has shown no decrease in fertility, but there has been a decline in milk production and size, with a tendency to a lighter shade in color.

A statistical study by the New York Cornell station of the effect of the age of the parents showed that a large proportion of high producers are the first calves of immature dams, indicating that age of breeding has little effect on the offspring.

At the Ohio station the percentage increase in production from the first to the third generation of Holstein grades, starting with scrub cows with purebred Holstein bulls, was from 61 to 231 per cent in milk production and from 55 to 153 per cent in butterfat production.

Calf feeding.—At the Washington station calves made normal growth on a homemade calf meal, consisting of 40 pounds corn meal, 20 pounds alfalfa leaves, 20 pounds wheat bran, and 20 pounds linseed meal. Two pounds of this mixture scalded in 1 gallon of water was equal to 1 gallon of whole milk.

Gains of calves fed dried and semi-solid buttermilk were equal to those fed skim milk, in experiments at the Minnesota station, and the animals remained in especially good health. A ration deficient in vitamin B gave positive results only after a period of eight or nine months. The effect was not very marked even then, and was shown mainly by a poor appetite and general lack of thrift.

Normal growth in weight was made at the Missouri station by heifers when 13.4 per cent of the total net energy for maintenance plus growth was furnished by protein in the ration. Higher protein planes were much more efficient in promoting growth with Holsteins than with Jerseys.

Milk secretion and production.—Studies on a Holstein herd at the Maine station showed that cows with larger measurements had slightly larger yields, but no relation was found between the dam's percentage of butterfat and the daughter's milk yield, or vice versa. There seemed to be a slight relation between the granddaughter's butterfat percentage and that of the maternal granddam, and only a slight relation between the granddaughter's milk yield and that of the maternal granddam. Likewise the relation was slight between the granddaughter's butterfat and the paternal granddam's butterfat. All of the data indicated that only ancestors in the first and second generations have any pronounced influence on the milk yields of their progeny. A cow's milk yield and butterfat percentage can best be predicted from that of her dam and full sisters.

The energy value of the milk solids is, according to the Illinois station, the most equitable basis for the comparison of the production of cows, milk yields being corrected for the influence of fat content, to the physiological equivalent of 4 per cent milk, by the equation $FCM=4M+15F$, where F C M means fat corrected milk, M the actual milk yield, and F the actual fat yield in pounds.

A definite relation between the concentration of the blood and that of the milk during the winter was indicated by investigations at the Missouri station. There was found to be a constant monthly percentage decline in the amount of milk from the second month of lactation, this being regular throughout the whole lactation period. Maximum production was at 7 or 8 years of age. Tests showed that the average monthly decrease in milk production for all breeds was very uniform, the production during the twelfth month being approximately 50 per cent of the production during the best month. The principal variations in milk production, aside from that due to advance of lactation, were found to be caused by changes in pasture during spring and summer. Cows calving in the fall and winter months equaled or excelled the average production, but those calving during the summer were generally below the average. Increase in weight followed closely the increase in milk secretion. Grouping animals of a given weight, regardless of age, showed an increase in production with the weight. Milk production appeared to be dependent upon two factors—age and weight. In Jerseys an in-crease in body weight of 100 pound with age was accompanied by an in-crease in butterfat production of little over 100 pounds per year. Mil secrétion increased with the bod weight of the cow to the age whe maximum body weight was reache (8 years), when it took a downwar course and steadily declined with ag When the ration fed to dairy cows wa reduced 50 per cent there was a de-cided increase in the percentage of fa in the milk, the peak being reache about the third day and remaining s during the test of 10 days. When th animal was put back on normal fee the fat percentage decreased and re-mained below normal for 10 days After milking the percentage of fa in the milk secreted fell, reaching minimum in 16 hours, and then in-creased somewhat.

The use of milking machines ha little or no influence on the yield o milk in experiments reported by th Texas station, but increased the bac-terial count unless special precaution were taken.

Soiling versus pasture.—The Montan station found pasture feeding muc more economical than soiling, eve though slightly less land is require and the production is slightly highe with soiling.

Silage.—Medium-mature corn silag was found by the Pennsylvania sta-tion to be better than green silage fo milk production, producing about 8. per cent more milk. In a compariso of early, medium, and late-maturin varieties of silage corn at the Con-necticut Storrs station, all bein planted and harvested on the sam day, the pounds of silage necessary t produce 1 pound of milk were, for th early 3.5, medium 4.2, and late 5.4 The amount of milk produced pe acre was, with the early 7,078 pounds medium 7,663 pounds, and late 7,52 pounds.

Sorghum silage was found by th South Carolina station to be 95 pe cent as efficient as corn silage in th production of butterfat, practicall equal to it for maintenance of bod weight, and with a slight advantag over corn silage for milk productio It greatly outyielded corn in tonnag per acre.

Sunflower silage proved to be abou equal in value to corn silage for th production of milk and butterfat, a the Georgia station. The iodine num-ber and refractive index of the butter-fat was slightly higher on the sun-flower silage ration. A comparison o

sunflower and oat-and-pea silage for dairy cattle, at the Montana station, gave practically the same results, but as the tonnage of the sunflowers was much greater there was considerable advantage in favor of the latter. A similar comparison of oats and vetch, corn, and sunflower silage, at the Oregon station, showed clearly an advantage for oats and vetch, considering yield, adaptability, cost of production, and feeding value.

Soaked beet pulp proved less palatable than corn silage in experiments at the Utah station, but those animals that would eat it maintained the full milk flow as well as those on the silage.

Soybeans.—A comparison, at the Indiana station, of soybeans, ground or as oil meal, with linseed and cottonseed meals in the dairy ration showed that the ration containing soybean-oil meal plus a mineral mixture required less feed for milk and fat production than the other two supplements, but all were very similar in their effect on production. At the Iowa station dairy cows were fed cracked soybeans up to 4 pounds daily for 100 days, with cracked corn and ground oats, with no unfavorable results and no scouring. Soybean-oil meal was found to have identical value for milk and butterfat production as old process linseed meal. In a comparison of soybean meal and cottonseed meal at the Mississippi station, the former tended to cause a higher fat content in the milk, but there was a greater loss of body weight of cows fed soy beans than those on cottonseed meal.

Milk and cream.—In a comparison of the methylene blue test and bacterial counts as a test for milk, at the New Hampshire station, no very close correlation was found, except in the reduction time of the methylene blue and the keeping quality of the milk. There was no close correlation between the bacterial counts in milk kept until it soured and the reduction time. The initial acidity was no index as to how long a milk would keep. The milk of Holsteins was found to be uniformly lower in initial bacterial count than that of Guernseys or Jerseys, by the South Carolina station. If there was a low initial bacterial count it remained so for some hours, but if the initial count was high it increased rapidly.

Contrary to theories that rennin action involves the destruction of the effects of a protective colloid in milk, it was found by the Minnesota station that a colloidal dispersion of calcium caseinates clotted like natural milk with rennet, at the proper temperature and hydrogen-ion concentration, in the presence of a trace of free calcium ions.

There appear to be eight valences and four distinct compounds of casein with alkali possible, according to studies at the New York State station. One definite compound of casein and calcium has been established with 1.8 per cent calcium. Some of the calcium compounds show plasticity when heated, indicating a colloidal character.

"Albumin" milks, made by mixing whey with cream, gave excellent cream layers, in experiments at the Minnesota station, and pasteurization increased the cream layer, contrary to the results with "casein" milk. Artificial whole milk creamed well at ice-water temperatures, but very poorly after pasteurization at 63° C. for 30 minutes. The removal of soluble salts seemed to have little effect on the creaming of raw milk, but salt-free milk had a very poor creaming ability after pasteurization.

The chemical composition of colostrum was found, by the Missouri station, to change rapidly with each milking, until it became normal milk, on about the third or fourth day. The main change is in the globulin and sugar, the former decreasing rapidly and the latter increasing. Colostrum has a considerably higher hydrogen-ion concentration than normal milk.

Wide variation in the citric acid content of normal milk, which may have a bearing on the selection of milk for the making of starters, was reported by the Iowa station.

Studies on the farm storage of cream, at the Indiana station, indicated that there is a change on the fifth day and that butter made from cream 5 or more days old does not score as high as that 4 days old or less. As a result of this study, creameries are now paying a premium for cream not over 4 days old and this practice has been adopted by seven or eight neighboring States.

Butter.—Butterfat heated to 175° F. for three hours and stored at temperatures of 0 to 35° kept well as compared with butter and cream so treated, in experiments at the Vermont station. Butter oil was held at a higher temperature than ordinary cold storage for several months, the change in temperature not having so much effect on it as it did on butter.

With butter that would not stand storage, the oil was separated, stored, and made over into a good product, first being made into a cream and from this into butter, which was scored high by experts.

Salt had no noticeable effect on the keeping qualities of sweet-cream butter or in preventing hydrolysis of the proteins, in tests at the Indiana station.

Contrary to the general belief among butter experts, the presence of large quantities of peroxidase in butter had no detrimental effect on the quality after six months' storage, in experiments at the Minnesota station.

Butter made from poor cream with a high bacterial count, which had been pasteurized, was found by the Michigan station to contain the enzyms capable of ruining the butter.

Fishy flavor of butter was found by the Wisconsin station to result from bacterial decomposition of lecithin, with the formation of trimethylamine, due to high acid, high salt, or oxidation as a result of overworking in the presence of iron or copper salts.

A distinct metallic flavor resulted from hanging strips of copper, iron, and zinc in milk cultured for buttermilk beverage, in experiments at the Oklahoma station. Tin and aluminum did not produce this effect.

Cheese.—Clarification of milk was found by the New York Cornell station to change only slightly, if at all, the composition of milk. The fat loss in the whey was slightly less with clarified milk than with the same milk not clarified. Clarification affected the yield of cheese as a result of losses during the process of manufacture and the moisture incorporated with the cheese. Clarification improved the quality of the cheese, and such cheese kept better in storage than that from unclarified milk.

The "stinker" odor in Swiss cheese was found by the Wisconsin station to be due to a combination of organisms, which may readily occur in milk, rather than to any single type of organism.

Ice cream.—Studies at the Illinois station showed that proper homogenization of an ice-cream mix improved the texture and resistance of the resultant ice cream. Homogenized mixes required less milk solids than unhomogenized to produce ice cream of equal quality. The temperature and pressure employed in the homogenization process affected the texture and resistance of the ice cream. It was possible to secure greater overrun from homogenized ice-cream mixes than from unhomogenized.

A direct relation between the percentage of sugar added to the mixture and the hardness of the finished ice cream and its ability to stand exposure to summer temperature, was shown by the Missouri station. With increased increments of butterfat, the viscosity showed a gradual increase. The time required for the mixture to begin freezing varied directly with the fat content, and the time required to whip the mixture decreased with increased fat content, resulting in a decrease of the total time required to freeze. The overrun increased slightly with increased viscosity. Ice cream containing the higher percentages of butterfat retained its original form over a longer period of time. Ice creams with 10 to 12 per cent of butterfat gave the best flavor, body, texture, and salable condition.

A bacteriological study of ice cream, by the Kansas station, in cooperation with commercial creameries, showed efficiency of pasteurization to be the most important single factor governing the bacterial content of ice cream, that it is practicable to produce ice cream containing fewer than 100,000 bacteria per gram, and that when it contains excessive numbers there is some factor in the process of manufacture that has been neglected, which may be a low grade of material, inefficient pasteurization, unclean utensils, or failure to control the temperature of the mix during the aging process. The use of homogenizers was found to increase bacterial count, by breaking up the clumps of bacteria.

Studies of gelatin for ice cream, at the Oklahoma station, showed that the quality of the gelatin varies greatly, and much contains large numbers of bacteria. An apparatus has been devised for testing strength, consisting of a plunger dropping into a 5 per cent solution of the gelatin, held over night to jell. This is now on sale and it is believed it will lead to a standardization of this material. Studies on factors affecting viscosity showed that acidity is not necessary and that an overrun of 100 per cent can be produced without it.

The rate of development of viscosity is not in direct ratio with acid development and is most rapid during the first 48 hours, according to the Georgia station. Pasteurization decreased the viscosity of the ice-cream mix, but on aging for 48 hours the pasteurized mix regained its viscosity to some extent.

Tests of acidifying the mix, at the Nebraska station, showed that the frozen cream retains the lactic acid flavor and is objectionable. It serves no useful purpose as it has no noticeable effect upon the physical make-up during the aging and freezing of the mix and is not recommended. Excessive aging tended to decrease the viscosity of the mix and caused a decrease in its ability to preserve a smooth texture. The optimum aging period for a normal mix was between 24 and 48 hours.

The percentage of total solids was found by the New York Cornell station to be the determining factor in sandiness.

The size of the air cells and water crystals was shown by the New York State station to be the main factor in the smoothness of ice cream. A greenish black discoloration which sometimes occurs in chocolate ice cream was found to be caused by rusted iron on the ice-cream can combining with tannin in the cocoa to form an iron tannate. Cocoas were found to vary largely in tannin content. The discoloration can be prevented by the use of well-tinned or paper-lined ice-cream cans.

VETERINARY MEDICINE

Horse diseases.—Swamp fever was not transmitted to the horse after passing it through the pig, at the Texas station. Pigs showed no change in temperature when inoculated with strong virus. The Wyoming station found the virus of this disease in the nasal secretion of infected horses.

The North Dakota station reported the death during the year of a horse which had been a carrier of swamp fever in mild form without anemia since 1908, but finally developed an acute and quickly fatal form of the disease. Salvarsan was tested as a treatment, with negative results.

In studies of orchard horse disease at the Washington station, it was not possible to produce a typical chronic case by the administration of lead arsenate. It appears that while this compound is probably primarily responsible for this disease, it does not produce it as a poison in the animal's body. The arsenate appears to produce in the growing alfalfa plants some change, as yet unknown, which causes the disease.

An apparently new species of streptococcus has been found in a number of cases of uterine infection in mares, by the Kentucky station. Vaccine prepared from it is apparently valueless and antistreptococcus serum also seemed to have no value.

Cattle diseases.—Blood taken from Brahman cattle, supposed to be immune to the tick and to Texas fever, and inoculated into Herefords raised above the quarantine line, transmitted the disease in one case at the Texas station. The Brahmans gave little temperature, being very resistant to the fever, although not absolutely immune.

Studies by the Texas station of an unidentified disease know as "down in the back" gave no indication of its cause and no positive evidence that it is due to poisonous plants. Culture of one organism from the disease produced it for a while and then became ineffective. The disease was produced in cattle by feeding ground bones from cattle that had died of the disease, the lesions being the same as in the field cases.

Studies of an unidentified hemorrhagic disease of cattle at the Nevada station indicated that it was due to joint or successive action of a number of microorganisms working together under favorable local conditions of food, water, and soil. There are indications that a protective serum or vaccine may be successful. Studies of an obscure disease of range cattle at the Wyoming station indicated the possibility of its being botulism.

In studies of sterility in cattle at the Minnesota station, cystic degeneration was found to be the most common pathological condition affecting the ovary. Prolapse of one or both walls of the vagina was found to be a fairly common condition in both dairy and beef cattle and a factor in sterility.

Sheep diseases.—It has not been possible to connect ictero-hematuria in sheep in any way with ticks at the Colorado station or to produce the disease by placing ticks on sheep.

In studies of pneumonia in sheep at the Montana station, cultures from infected animals gave either one of the Pasteurella group or a diphtheroid bacillus as the causative organism. In inoculation experiments the diphtheroid organism was recovered from the lungs of sheep inoculated with that organism, but no results were obtained with Pasteurella and it is believed that the diphtheroid bacillus is the causative organism. The disease develops very slowly under good care. Culling and immediate marketing of sheep showing symptoms are recommended for control.

Feeding experiments with sachahuista (*Nolina lindeheimerina*, *N. tex-*

ana, and *N. erumpens*), which are thought to be a cause of swell head in sheep and goats, gave negative results at the Texas station.

Swine diseases.—In studies of the posterior paralysis of swine at the New York Cornell station, lack of minerals was found to be definitely connected with the development of the trouble in some cases but not in others. Histological studies suggested scurvy as well as improper mineral assimilation. It is believed that at times the symptoms may be connected with rickets and at other times with scurvy, or that both may occur simultaneously.

Swine dysentery was found by the Indiana station to be a definite disease with diphtheritic mucous membrane lesions in the colon. Amœba, spirilla, balantidia, and comma-shaped organisms were found in the colon, but these were not successfully grown in cultures. Pig typhoid was found to occur most frequently in late winter and early spring pigs. It was not possible to reproduce the disease by placing healthy pigs in lots with sick animals with two or three months' exposure. The history and lesions suggest food deficiency as one of the causes.

Poultry diseases.—Aspergillosis in chickens was found by the Oklahoma station to be caused by a black mold, causing heavy losses in some cases. The mold spores become more virulent by passing through poultry. Renal coccidiosis of poultry was found to be similar to blackhead in turkeys, but is confined to the kidneys and intestines, and is scattered in the droppings, this being the only source of transmission. It is best treated by sulfur carbolate in the drinking water.

In white diarrhea studies at the Rhode Island station, two different strains of *Bacterium pullorum* have been found which agglutinate differently but show no other differences and grade into each other. Reaction was sometimes obtained with one strain in apparently healthy birds, but not with the other. Temperature had no effect on the occurrence of the disease. Tests at the Kansas station showed that 100 per cent mortality may result from inoculating fertile eggs with *B. pullorum*. The disease had a marked effect on the hatchability of eggs, which was lowered; but not all eggs laid by an infected hen contained the organism, and the hatchability was dependent upon the number of organisms present in the egg, the virulence of the organism, and the resistance of the chick embryo.

A paratyphoid organism was isolated from cases of "keel" of ducklings, by the Connecticut Storrs station, which resembles *Bacterium anatum*, and its relation to the disease was demonstrated. Autopsies showed pathological changes in the ovaries. Four strains of the organism were isolated from different localities. The organism does not react to *B. pullorum* serum. The disease is very fatal.

Studies of leg weakness in chicks at the Indiana station showed that the trouble developed commonly when the chicks were kept indoors until 4 to 6 weeks of age and could be cured by feeding them cod liver oil or by putting them outdoors in the sunlight. The bones showed the same changes as occur in rickets in other animals.

Examination of a large number of cases of roup in chickens at the Michigan station indicated that a great deal of so-called roup is not primarily infection but is due to nutritional disturbances, sometimes associated with faulty diet and sometimes with intestinal parasites.

The North Carolina station found fowl septicemia to be due to the same cause as fowl typhoid, the organism being identified as *Bacillus sanguinarium*. Typical disease was produced with cultures of this bacillus, and a vaccine was prepared that was effective in stopping the disease.

Anthrax.—Studies at the Louisiana station show *Tabanus fulvulus* to be one of the most common and certain carriers of the anthrax organism. This fly feeds freely on all kinds of quadrupeds and acts wholly as a mechanical carrier. Five other species of Tabanus and two of Chrysops were found to act as carriers, while three other species of Tabanus did not carry the disease. Experimentally *T. fulvulus* gave 50 per cent of experimental infections with guinea pigs, other carriers producing less. The virulence of the organism was not reduced in the soil, soil water, or stagnant or running water, nor was its vitality destroyed by alternate moistening and drying. Vaccines were found to be efficient preventives.

Hog cholera.—The Indiana station found that cholera blood of known virulence spread on glass plates in a thin layer and exposed in a well-lighted room for 7 days in August, when fed and injected subcutaneously into pigs, produced symptoms of the disease; but, with virus so exposed for 8 to 9 days, none of the pigs developed symptoms. Urine from a cholera hog 7 days after inoculation with virus did not produce the dis-

ease when fed to susceptible hogs, but the feces were virulent. The urine of a hog 10 days after inoculation was infectious. In the early days of inoculation, the urine was apparently nonvirulent. Virus died out in a short time in a decomposing body.

Hemorrhagic septicemia.—In experiments at the Nebraska station virus prepared from strains of *Bacillus bipolaris septicus* as bouillon cultures incubated for 24 hours showed marked protective qualities but induced only an evanescent passive immunity which disappeared within a week. Injection of virulent cultures into animals treated with serum did not make the immunity more lasting. The Colorado station has isolated a large number of strains of the bacillus.

Tuberculosis.—It was found at the Wyoming station that injection of the avian type of tuberculosis into cattle produced lesions very similar to the skin form of tuberculosis in cattle. The injected animals gave positive reactions to the intradermal tests for tuberculosis but negative or doubtful reactions to the subcutaneous and ophthalmic tests.

The examination of material from 26 tuberculous swine at the Nebraska station showed at least 21 to be definitely of the avian type, and on all the farms from which these hogs came the poultry flocks were found to be infected, but on only one were the cattle infected.

The avian type of tuberculosis was also found by the Wisconsin station to be more common in hogs than the bovine type, and avian and porcine tuberculosis were shown to be intertransmissible. A bacteriological study of one lot of tuberculous hogs, however, showed only 2 cases to be avian, 13 being bovine.

Experiments at the Illinois station also suggest that the avian type of tuberculosis may be communicable in some degree to other animals. Calves and pigs may be infected experimentally, but the lesions so induced are generally benign in character. Pigs fed chicken with tuberculosis of the avian type showed lesions in the mesenteric lymph glands. The tuberculous lesions induced in pigs by certain strains of the avian organism, upon feeding and injection into healthy chickens failed to produce typical lesions of tuberculosis, suggesting that the initial avian infection in swine may not be highly communicable, but some strains are readily transmissible from chickens to swine and back to poultry with the production of characteristic lesions. English sparrows and pigeons may contract the disease from chickens. The tuberculous infection of the English sparrow may be communicated to poultry and pigs by injection or feeding the tuberculous tissue or the cultures of the organism.

Parasites.—*Sarcocystis tenella* was found to be a common parasite in the muscle of sheep by the Wyoming station. Infection was light in the dry lot but heavy in pastures. The disease was transmissible directly through fecal infection and was therefore higher where animals are confined to a limited area. Experiments with animals kept in screened inclosures to prevent insect transmission gave negative results. Infection occurred from late spring to late fall. There appeared to be no infection with the tapeworm (*Thysanosoma actinioides*) in dry lot, and infection was not very often harmful.

A study of the stomach worms of sheep at the Texas station showed that copper sulfate and sodium arsenate mixtures were not wholly effective. A 100 per cent kill was not secured with copper sulfate in maximum doses with sheep, but was more successful with goats. With goats a 3 per cent solution can be safely used, but with sheep it is not safe to use stronger than a 1.5 per cent solution. Carbon tetrachloride and nicotine sulfate gave good results as agents to eliminate the worms. Like results were obtained with nicotine sulfate at the Connecticut Storrs station. Copper sulfate was not so effective.

Bromoform was found to be very effective in killing the screw worm, in experiments at the Texas station, when used in small quantity under a covering of wool or cotton, and it is not so irritating as chloroform. The most effective fly repellent tried was pine tar 50 per cent, glycerine 25 per cent, and castor oil 25 per cent. The goat louse was shown not to occur on wild animals, and would not stay upon them when so placed. For its control a standard arsenical dip, with two dippings at 10-day intervals, was most effective.

The Oklahoma station found lye to be useful in ridding infected poultry of tapeworms. Roundworms responded better to tobacco than to lye, and carbon tetrachloride was also effective. At the California station a single treatment of nicotine sulfate with aluminum silicate given in capsules was found to be 100 per cent effective

for *Ascaridia galli*, and combined with tobacco dust 85 per cent effective for cæcal worms.

It was found at the Kansas station that 24 per cent of young birds die in from 10 to 14 days after infection with nematodes, the survivors being resistant and doing well thereafter. The Rhode Island station found that Heterakis does not migrate in the body of the bird. It causes irritation in the cæcum which may, perhaps, lead to blackhead. At the North Dakota station, sodium fluoride used either by dipping or dusting was effective in destroying lice, but resulted in some decrease in egg production. Mites were controlled by a 5 per cent solution of creolin in kerosene oil.

Poisoning.—In studies on white snakeroot poisoning, at the Indiana station, horses fed 1 pound a day of the weeds cut in the fall, dried, and kept for three months first developed symptoms in five days, which increased until death occurred on or soon after the eleventh day. The symptoms differed from those getting the plant in the field, where the effects show quickly as nervous symptoms. Cattle die from it quickly, often without showing symptoms. Pigs showed no ill effects from eating the weed. Chemical studies show that the toxic principle is very volatile and is probably a glucoside.

Poisonous plant studies at the Nevada station showed that Tetradymia has a high percentage of volatile oil but this does not carry the poisonous principle which is found in the benzol extract. It was most abundant in the young growing tips. *Atriplex canescens* is believed to be poisonous to sheep at any stage of growth. It contains a saponin, believed to be the poisonous principle, which produces homolysis. A small buttercup with toxic properties has been found. Feeding experiments with larkspurs have failed to show any poisonous effects. Studies of the alkaloidal poison of *Delphinium menziesii*, at the Wyoming station, show that this species is the most poisonous of all the larkspurs. Two types of toxic alkaloid were found to exist in *Lupinus argenteus*, one solid and the other liquid.

TECHNOLOGY

In investigations at the Louisiana station on the clarification of cane juice and the deterioration of cane sugar it was found that a reversal of the usual procedure of sulfitation, in which the juice is first clarified with lime and then lightly sulfured to attain a bleaching of the coloring matters, gave excellent results if carefully carried out. It gave a much better elimination of impurities, particularly of lime salts, and much less sulfur was required, reducing the sulfur content of the molasses. It was found that filtration with carbons changed the predominant type of organisms in juices and retarded the rate of development of those remaining.

It appeared that to conform to the "factor of safety" a sugar must be crystallized from a solution of such purity that it will yield an exhausted molasses as a protective film for the crystals. Sugar deterioration was shown to be dependent upon surface exposure as well as upon density of the film of molasses surrounding the sugar crystals.

A great variation was found in the inverting power of the mold fungi causing the deterioration of sugar. They were very susceptible to carbon dioxide and by introducing certain races of Torula, or nonsporulating yeasts, these grow on the molasses film of the sugar, producing carbon dioxide, and prevent the molds from developing. This has additional advantages in that their destruction of the reducing sugars and their action on invertase cause an increase in the polarization of the sugar during storage, and by the elimination of levulose and other reducing sugars make it less hygroscopic and hence less susceptible to moisture absorption and resulting deterioration. It was found that the condition of infection of sugars, quantitatively and qualitatively considered, had a marked influence on the keeping quality. The method was ineffective when applied to sugars which contained their original molasses film. The most important factor contributing to the hygroscopic nature of white sugars was found to be the presence of fine grains and sugar dust.

At the Minnesota station, conclusions from two seasons' investigations of the possibility of making sirup from cornstalks are that a good quality of cooking sirup can be made from sweet cornstalks but that a table sirup can not be expected. Since the smaller varieties yield only 30 to 40 gallons per acre and the larger ones 100 gallons or more, the manufacture of sirup will be feasible only when the larger varieties are used. Under proper conditions the manufacture of sirup as a cannery by-product may be a profitable enterprise.

In studies on vinegar making, at the Iowa station, alcoholic fermentation was found to be complete in about a month, acetic fermentation begin-

ning before the alcoholic ended. Good vinegar was made from frozen apples if they were promptly used, no starter being required.

AGRICULTURAL ECONOMICS

Farm management.—A study of exceptionally profitable farms in a series under observation at the Kentucky station indicated that the principal factors responsible for their success were (1) that the labor and teams were so handled us to secure maximum efficiency, (2) that crops were limited to an acreage that could be cultivated well at a moderate cash outlay, (3) that the tobacco produced was of high quality, and (4) that a large proportion of the farms was in grass and more livestock was kept than on the average farm in the section.

Cost of production of wheat.—Studies on the cost of production of wheat, at the Kansas station, in 1922, showed this to be $1.30 to $1.40 per bushel where there was an average yield of 14 bushels per acre, the product selling at $0.90 to $1.05. In a study of the marketing of Kansas wheat, the owners of 63 per cent of the wheat involved in the study believed in and practiced farm storage, 13 per cent did not believe that it pays to store wheat but were compelled to store because of marketing difficulties, 5 per cent believed it paid to store and had facilities but nevertheless sold direct from the machine, probably because of credit factors, 3.5 per cent believed in storage but lacked space, and 8 per cent sold directly from the machine, believing that practice paid best in the long run. Less than 5 per cent of the wheat crop was found to be marketed early because of insufficient farm storage space.

Cost of producing apples.—Results of a study of 64 orchards by the Minnesota station, totalling 487 acres, showed the average cost to be $0.839 per bushel and $125.60 per acre. The average returns were $1.53 per bushel and $215.99 per acre.

Cost of milk production.—Data secured by the Wisconsin station show that on farms whose herds sold less than 5,000 pounds of milk per cow per year there was a return of 3.3 per cent interest on the total farm investment, with no compensation for time; those with 5,000 to 7,000 pounds of milk per cow received 4.7 per cent interest with no compensation; and those with over 7,000 pounds per cow received 5 per cent and $244 for their time.

In data from 172 farms, secured by the Washington station, the cost of producing milk varied from $1.81 to $4.56 per 100 pounds. The basic requirements for producing 100 pounds were grain, 17.7 pounds; hay, 38.2 pounds; succulents, 47.1 pounds; pasture, 3.1 days; and man labor, 2.3 hours.

AGRICULTURAL ENGINEERING

Noteworthy progress has been made in developing investigation in agricultural engineering at the experiment stations. Some more recent examples of work in this field are as follows:

Tractors.—The Nebraska station found that in general total engine weight of tractors increases as the engine weight per brake horsepower increases. The general trend is also toward a reduction in the tractive efficiency with an increase in the total weight of the tractor beyond 4,500 pounds and a decreased efficiency with tractors lighter than 4,000 pounds. With the wheel tractor the tractive efficiency tends to decrease as the total weight per drawbar horsepower increases, varying inversely as the weight on the drivers per drawbar horsepower. It was also found that the lightest weight tractors are not so efficient as those of medium weight, except in the case of live-axle-driven machines. A slight advantage is also noted in the gear drive over the live-axle drive, and no one number of gear reductions apparently has the advantage with respect to tractive efficiency.

Fuel consumption tended to increase with an increase in the piston displacement. The lowest fuel consumption was secured with engines having a cylinder diameter of between 5 and 6 inches. With horizontal cylinder engines the fuel consumption tended to decrease as the weight increased up to approximately 7,000 pounds, after which the reverse was true. In the case of vertical cylinder engines there was a slight increase in fuel consumption until the 7,000-pound mark was reached, after which there was a marked decrease. The I-type engine gave better fuel economy than the L-head engine on all operating loads. The rated brake load gave better fuel economy than either the maximum or half loads. The fuel requirement on drawbar work was almost double that required on belt work per horsepower hour.

In tests of a number of representative fuel treating materials at the Nebraska station, about the same results were secured by proper adjustment of the carburetor without fuel savers as when these were used. Experiments at the California station in-

dicated the importance of proper carburetor adjustment on fuel economy and the impossibility of readily detecting rich mixtures by engine performance.

Experiments on wheel slippage at the Nebraska station indicated a tendency of the angle lug to pulverize the surface of the test track, after traveling over it several times, to such an extent that a good grip could not be secured. The spade lugs gave the best results on the track, due largely to the fact that they penetrated the ground to a sufficient depth to give a good grip and did not pulverize the surface. There was a slight decrease in the percentage of slip of the drive wheels as the total tractor weight increased.

Soil tilth.—Studies at the New Jersey stations showed that while limed soils have a distinctly superior crumb structure, as interpreted on the basis of modulus of rupture, factors other than the direct flocculation of the colloidal material of the soil through the action of the lime are active in promoting this condition. The action of lime was distinctly differential, depending apparently upon the nature and type of the soil. In a clay soil the effect of liming was more or less promptly noticeable through a decrease in the modulus of rupture. In a loam soil the tendency was apparently in the opposite direction. The modulus of rupture decreased with the progressive neutralization of the alkalinity of both natural and synthetic alkali soils.

Duty of water in irrigation.—Experiments at the New Mexico station indicated that the average duty of water on alfalfa was 4.67 acre-feet per acre producing 5.47 tons per acre. The largest yield per acre-foot of water was produced on the soils receiving the smallest head, regardless of the length of plat. Studies at the Utah station have resulted in the development of a mathematical method of determining the economical use of irrigation water under various conditions of water supply, irrigable land, cost of crop production, and value of crops.

Soil moisture movement.—Studies at the Arizona station on mesquite and cottonwood soils showed that in the summer the water table falls as much as 5 inches during the day and recharges during the night. There is no such fluctuation in winter, except that which may be accounted for by barometric pressure.

The maximum movement either upward or downward of moisture from a moist soil into a dry soil was found by the California station to be less than 7 inches during a period of 4.5 months. The presence of a water table did not decrease the rate of percolation, and an increase in head resulted in a greater loss by percolation. The rate of percolation through a gravelly phase of a sandy loam was about twelve times greater than through loam, all other things being equal. The variations in the rate of percolation were dependent upon the effective head operating on the soil column, which varies according to the dispersion of the soil colloids, the loss or gain of organic material, the gradual silting up of the pore spaces of the soil, and the loss of colloidal or fine clay material in the drainage water. The effective head also varied with the flow of water at any point in the soil column and was dependent upon time. The hydraulic gradient in a column of soil with a head of water operating upon its surface is represented by a uniform curve which approached a straight line in about 10 days. A dilute solution of copper sulfate increased the rate of percolation by altering the soil structure.

Tests at the Washington station showed that on land having a slope of 0.2 foot per 100 feet water penetrated to a depth of 4 feet in 48 hours, while on land with a slope of 6 feet per 100 feet it penetrated only 3 feet in 72 hours. The rate of lateral distribution was about proportional to the downward penetration in each case. The lateral and downward movements of water from a furrow were nearly equal for the first 12 to 24 hours, after which the lateral movement slowed down to almost nothing in from 36 to 48 hours.

The yield and net profit per acre-inch of irrigation water were almost doubled by rotation and manure and the water requirement per pound of dry matter was reduced nearly one-half in experiments at the Oregon station. A rich and well-balanced nutrient solution in soils resulted in a low water requirement for crops.

Soil moisture conservation.—Results of studies at the California station indicate that the hygroscopic coefficient is the most logical point upon which to base all calculations relating to the moisture content of the soil.

Evaporation within and without the laboratory showed very similar characteristics in studies at the Colorado station, but the maximum rate did not occur at the same time of day. The effect of wind on the rate of evaporation was very marked. Studies at the Utah Station showed that

an effective mulch of 1 inch of straw is capable of holding 60 per cent more moisture in the soil than is retained without mulching. The loss of moisture from the soil was correlated with the percentage of moisture retained by the mulch. The effectiveness of mulching and cultivation increased with their depths, and the rate of evaporation from soils under mulch varied according to their moisture contents, the finer soils losing the most water. While cultivation and soil mulching saved moisture, the evapotranspiration ratio was least with no mulch or cultivation. Fall plowing conserved more moisture than spring plowing and 4-inch cultivation was more efficient than 6-inch cultivation.

Irrigation of alkali soils.—The California station found that alkali water may be passed through certain soils for some time without causing an accumulation of salts in the soil. Sodium carbonate may produce bad effects on the soil very quickly, but this may be largely or entirely prevented if chemically equivalent amounts of gypsum are added to the water before applying it to the soil. The presence of calcium carbonate and organic matter such as alfalfa meal may still further counteract the injurious effects of alkali water on soil.

A condition of impermeability was found by the New Mexico station to develop on leaching an adobe soil containing about 1 per cent of sodium chloride. With good percolation this large amount of alkali was readily removed and leached below the toxic limit by a small amount of water. The chlorides were more readily removed than any other constituent.

In attempts to reclaim alkali soils by leaching with water and adding gypsum, the California station found that the removal of all but negligible amounts of alkali salts from the first 6 feet or more of a heavily impregnated soil required many months of leaching. Soluble matter not carried below the 6-foot level was found to return near the surface with the capillary water. Gypsum, acting as a flocculant, increased the rate of leaching. Chloride, nitrate, sulfate, carbonate, and bicarbonate were leached out in the order given. The removal of more than 0.5 per cent of sodium carbonate from a soil was a very slow process. Similar results, with special reference to the ease of removing sodium chloride and the difficulty of removing sodium carbonate, were obtained at the Utah station. The long unproductive period frequently following the leaching of alkali soils appears to be due to the removal of much of the readily available plant nutrient material, the poor state of tilth of the drained soil, and the occasional production of toxic lime-magnesia ratios.

Irrigation structures.—Experiments at the Arizona station showed that concrete linings of from 1 to 2 inches in thickness have been used successfully in irrigation canals in regions where the frost action is not serious. Present practice tends to make 1.5 inches the minimum thickness, but a greater thickness should be used for large canals and steep side slopes. Canals located on unstable foundations require increased thickness, beam effects, and reinforcing to resist side and bottom pressures and unequal settlement.

Sewage disposal systems.—Investigations at the Michigan station extending over a period of eight years indicate that the proper farm sewage disposal system for Michigan conditions involves the use of four units and two distinct processes of bacterial action. The units are an anaerobic and settling chamber for the decomposition of solids, a siphon chamber, a siphon, and an aerating system.

Biology of sewage disposal.—Studies at the New Jersey stations showed that very few fungi and algae occur in the Imhoff tank. The protozoa apparently increase in number with increasing depth, and as a rule the scum formed in the vents of the tank does not contain protozoa at all. The more abundant bacteria in Imhoff tanks are those which attack the most easily digested protein material. These bacteria were always present even in the highest dilutions, and their numbers apparently bore some relation to the character of the protein molecule. Both nitrification and nitrate reduction occur in the Imhoff tank. In nearly every case the scum in an Imhoff tank was found to be decidedly less alkaline than the influent and in nearly all cases less alkaline than the preliminary sludge, ranging in reaction from pH 6.8 to 7.6. A total absence of oxygen and hydrogen occurred in Imhoff tanks. Studies on sprinkling filters showed that the slimy film is composed largely of bacteria, microscopic animals, and fungi. The greater part of the effective nitrification was found to take place at the bottom of the filter bed throughout the whole year. Denitrification exceeded nitrification in the upper parts of the bed in the spring, and free ammonia was removed chiefly at the bottom of the bed.

Dairy sewage disposal.—Studies at the New York Cornell station showed that natural processes tend to destroy dairy wastes and render them harmless in a manner similar to that in which they assist in the purification of other organic wastes, and that supplemental methods of purification are needed only when the amounts of waste present are in excess of those which nature can handle without the development of undesirable conditions. It was found that from 75 to 95 per cent of the organic nitrogen could be removed from whey by adding a slight excess of lime over that necessary to neutralize acidity, boiling, and then passing the cooled effluent through a septic tank and a sand filter. The activated sludge method of treating dairy wastes proved impracticable. A sand filter purified milky waste septic tank effluents at rates ranging from 75,000 to 100,000 gallons per acre per day. A stone or lath filter purified such effluents at rates ranging from 300,000 to 400,000 gallons per acre per day. Some form of settling and holding treatment for milk wastes was found to be desirable. An Imhoff tank was found undesirable for this purpose. A septic tank, which should be designed to hold from one to three days' flow of waste, is recommended. Secondary sedimentation tanks were found to be a necessary part of a treatment plant in which the filter material is coarse. Milk wastes could be sufficiently purified by tank and filter treatment so that fish showed no distress in the undiluted effluent.

Drain tile.—Studies at the Wisconsin station showed that the better grades of concrete drain tile compare favorably with good shale tile, but only the best show signs of permanence in peat. In general, comparatively poor concrete tile will stand up well in clay subsoils. Clay or shale tile that absorb water to the extent of more than 14 per cent of their dry weight are undesirable, and concrete tile with an absorption greater than 7 per cent are too porous for use in peat or sand under peat. The deterioration of concrete in peat is less marked where dense walls are secured by firm packing, which seems practicable only in the thick walls of tile 12 inches and larger in size.

STATION WORK ON INFECTIOUS ABORTION

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BOVINE INFECTIOUS ABORTION

Importance.—Infectious abortion is probably the most important insidious disease with which the livestock farmer of this country has to contend and presents, according to the Michigan station (*1*),[1] the greatest economic disease problem which confronts the breeder of purebred cattle. According to the Connecticut Storrs station (*2*, *3*), it ranks with tuberculosis and hog cholera in importance and is more insidious even than tuberculosis and more far-reaching in its after effects. It not only causes loss of the calf but results in decreased milk flow, possibly permanent sterility of the cow, and in other harmful effects.

The Arkansas station found (*4*) that in some sections 70 per cent of all cattle herds are infected. Tests by the Wyoming station (*5*) showed a large percentage of cows on the range to be infected. The Wyoming station (*6*) concludes from observations made in that State that a large percentage of the so-called dry cows are sterile because of abortion infection.

Cause.—*Bacillus abortus* is generally considered to be the cause of the abortion disease, but the California station (*7*) has found herds in which abortion occurred, although agglutination tests for *B. abortus* were negative. The station found *B. abortus* to be present in the supramammary lymph nodes of first-calf cows, the blood of which was negative to the agglutination test. In a small percentage of cases, negative for *B. abortus*, organisms including *Vibrio fetus* and possibly *Bacillus pyogenes* have been found, that must be taken into consideration (*8*). The results of investigations at the Kansas station seem to suggest that *B. abortus* is not the sole incitant of abortion disease (*9*). Agglutination tests of the blood of range animals in the mountainous district of Colorado (*10*) indicate that a considerable proportion of the abortions in such herds in the State may be due to some factor other than *B. abortus*. The Oregon station (*11*) found many animals that had aborted but failed to give positive blood tests. However, *B. abortus* is stated to be responsible for 90 per cent of all abortions in Oregon (*12*). Studies at the Michigan station (*13*) indicate that there is a large number of nonvirulent strains of *B. abortus*.

The Missouri station (*14*) found that *B. abortus* infection may localize in the liver and probably also in the spleen, as occurs in guinea pigs.

Cultivation.—Maximum growth of *B. abortus* was obtained at the Oklahoma station (*15*) by using media that had an H-ion concentration of 7.4. A rapid method for the cultivation of *B. abortus* perfected by the Minnesota station (*16*) consists in the use of horse serum agar culture media, using 10 per cent naturally sterile horse serum and adjusted to approximately pH 7–7.2. Cultures made on such media and incubated in an atmosphere of 10 per cent carbon dioxide or hydrogen showed colonies at the end of the 24 hours and reached a maximum growth in 72 hours.

Substitution of liver or spleen for the beef of the ordinary beef agar was found by the Michigan station (*17*) to give a medium in which growth of *B. abortus* was much more rapid than on ordinary beef agar. The spleen medium was further improved by the addition or 1 per cent starch or 1 per cent dextrose, or both, while the liver agar did not require the addition of carbohydrate. The use of an anaerobic jar as a container of the culture tubes was found to be more efficient and convenient than sealing the individual tubes with sealing wax. The medium found most satisfactory by this station (*18*) for the isolation of *B. abortus* from milk was liver infusion agar in which was incorporated sufficient gentian violet to give the dye a final dilution of 1 : 10,000. The medium was adjusted to an H-ion concentration of between pH 6.6 and 6.4 by the colorimetric method, using brom-thymol blue as indicator. The medium should be prepared without

[1] Numbers in parentheses refer to references, page 81.

excessive heating and filtered through glass wool instead of cotton or paper.

Diagnosis.—The complement fixation method was not found to be superior to the agglutination test for diagnosis of abortion, in tests reported by the Minnesota station (*16*). Remarkably close agreement in results was obtained by the two methods in a comparative study at the Kentucky station (*19*). The conclusion was reached, however, that it is very rare for cows to show agglutination in dilutions of 1 to 100 or above, unless they have been infected recently, and that it does not seem practicable to use the agglutination method alone. Both have been used with success at the Connecticut Storrs station (*2*) and the Wyoming station (*5*). The agglutination test was found by the Indiana station (*20*) to be valuable in diagnosing herd abortion, but not adequate for the more accurate diagnosis of individual cases of abortion.

A detailed account of the complement fixation test has been given by the Wisconsin station (*21*), but since this test is very complicated the agglutination test is more commonly used (*22*). Although, as pointed out by the Connecticut Storrs station (*2*), these reactions do not of necessity indicate that an animal is at the time of examination infected with *B abortus*—the disappearance of the organism from the host not being followed immediately by a similar disappearance of the antibodies—yet there is no doubt that such an animal, if not at the time infected, has within the past five or six months been an active carrier of *B. abortus*.

There is no definite correlation between a positive agglutination test and abortion, according to the Illinois station (*23*) ; but the presence or absence of infectious abortion in the herd may be established with accuracy by the serum agglutination test of all breeding animals.

From studies with guinea pigs the Michigan station concludes (*24*) that the intradermal test may be used to detect infection with *B. abortus* in connection with complement fixation and agglutination tests to differentiate between infection and immunity. Similar intradermal tests on cattle indicate that the test may be employed as a means of detecting animals which harbor live abortion organisms in their bodies.

The agglutination test, according to the Wisconsin station (*25*) must be made at least once every six months in order to detect incipient cases of infection. The application of the agglutination test to 2,400 animals in the herds in one community indicates, according to this station (*26*), that the test is an effective and practical measure for use in abortion control. This station's experience is considered to point the way to the possibility of establishing abortion-free accredited herds. Single negative agglutination tests, according to the California station (*7*), are not to be taken as definite evidence of the disappearance of *B. abortus* from the body of infected animals. The Oregon station (*27*) found a single maximum agglutination to be of no value in determining whether a cow will abort.

Repeated intravenous injections in experiments at the Minnesota station (*28*), and also injection into the sheath of pure culture of *B. abortus* raised the agglutination titer of the blood of young bulls; but the antibodies gradually decreased and *B. abortus* was not isolated in any case, even though the organs were carefully examined after slaughter. It was found that the blood of young calves did not have the same agglutination titer as that of their dams (*16*). Calves were found to give the same agglutination reaction as their mothers in experiments at the Connecticut Storrs station (*2*, *29*) and the Wisconsin station (*22*). The Connecticut Storrs station (*2*) found that after six months all calves were nonreactors. Thec omplement fixation test showed no advantage over the agglutination test in comparative trials at the Minnesota station (*16*). This station (*16*) found that the ingestion of colostrum quickly affects the antibodies present in the blood of the calf.

The long persistence in an animal of the specific serological reaction to *B. abortus* antigen is considered by the Missouri station (*30*) to be dependent on the persistence in the same animal of the living *B. abortus* microorganisms, and that they are present in an excretable condition.

Agglutination tests made simultaneously with blood serum and milk upon all of the cattle in the California station (*31*) dairy herd indicated no direct relation between the agglutinin content of the blood and that of the milk, since a few of the cows positive in blood were not positive in milk, and in most cases where blood and milk both were positive the milk showed a lower titer. In every case where *B. abortus* was isolated from the milk, the milk gave a positive reaction and *B. abortus* could not be isolated from every case in which the milk was positive to the agglutination test. It was

found that agglutinins may be present in the milk in cows that have aborted and in the milk of cows that have never actually aborted. Periodic agglutination tests upon the blood serum identified practically all the "carriers," inasmuch as no cow was positive consistently in the milk and not in the blood, although *B. abortus* was found once in the milk of a cow which had been negative in the blood and milk at every test.

Carriers and transmission.—The cow is apparently most dangerous as a source of infection at the time of calving or aborting. Cows inoculated artificially with *B. abortus* and kept isolated thereafter from other cattle for four years were found by the Missouri station (*32*) still to be carriers of the infection and at the time of parturition were capable of infecting nonreacting pregnant cows through their uterine discharges.

Ingestion has generally been found to be the principal means of transmission of infection. The Connecticut Storrs station, however, concludes (*29*, *33*) that transmission by the male is the most important means of spreading the disease. This station (*29*) failed to bring about infection by repeated administration of artificial cultures of *B. abortus* through the mouth, other chances of infection being eliminated. Infection was repeatedly accomplished, however, by painting the urethra with suspensions of *B. abortus* and applying them directly to the vulva. Small laboratory animals, including guinea pigs, rabbits, and mice, proved highly susceptible to infection by *B. abortus* by mouth, vagina, and urethra, as judged by the agglutination and fixation tests and in some cases by the death of the animal (*34*). Infection of calves before the age of 8 or 9 months was found to be extremely rare, and it was demonstrated that the disease is not transmitted from dam to calf (*2*). Observations by the Oregon station (*12*, *35*) appear to confirm the findings of other investigators that the organism lives only in the pregnant uterus and the udder and that infection enters the body through ingestion. Observations at this station (*27*) also showed that the animals are most apt to abort during the pregnancy in which the initial infection is received, and that animals infected during their first pregnancies are more apt to abort than those infected during later pregnancies.

Abortion is not inherited, and heifer calves are not infected by drinking infected milk, according to findings of the Oregon station (*12*, *27*). The Wisconsin station (*36*) showed the average time required for abortion to result after infection to be about 58 days.

The Connecticut Storrs station (*2*) found that the period of greatest susceptibility to established infection is apparently between the ages of 10 months and 3 years, or from the time of sexual maturity to the first parturition, after which early period the chances of permanent infection rapidly decrease. It was found that few cows changed from negative to positive after the fifth year.

In experiments at the Oregon station (*12*, *27*) breeding negative cows and heifers to negative bulls which had served positive cows did not result in infection. Exposure of pregnant cows and heifers in pens or pasture to abortion-infected cows and housing in infected barns were found to be active means of infection. Milk from the udder carrying *B. abortus* was not found by the Michigan station (*40*) to be an important factor in transmission of the disease. The California station (*41*) found the addition of infected cattle to be the manner in which, in the vast majority of cases, the disease is introduced into the herd.

In experiments of the Missouri station (*37*) two of seven heifers from a nonreacting herd bred to a nonreacting bull were fed cultures of the bacillus and aborted, the bacillus being recovered from the fetus. Two others which received injections of the bacillus under the skin developed a positive reaction, but carried their calves to within seven or eight days of maturity, the bacilli being recovered from the placenta, and the milk being positive. Two others, in which the bacilli were injected into the vagina, developed a positive reaction, calved prematurely, and the bacilli were found in the udder; and two in which the bacilli were injected into the teats also calved prematurely. Thus, irrespective of the manner of entry of the germs into the body, they appeared in the udder and uterus. The Missouri station (*30*) concludes that an immune abortion reactor does not as a rule discharge *B. abortus* in dangerous quantity except for a short period coinciding with the last several days of gestation and the cleaning period of approximately four to six weeks following parturition. Experiments with cattle that had been artificially inoculated with the living culture showed that the inoculated cattle continued to react (1) in cases where abortion had occurred following the inoculation, (2) in cases where abor-

tion did not occur, (3) in the case of sterility where the cow was repeatedly bred, and (4) in the case of sterility where ovulation and heat periods were absent. There is a weakening in the virulence of the infection after it has been carried for a number of years by a persistent reactor. On the other hand, the fact that old reactors may lose their resistance and abort, indicates the probability that the abortion infection may regain full virulence and produce disastrous results.

At the Missouri station (*38*) it was found that neither the bull nor the steer are as favorable hosts for *B. abortus* as the mature cow. The Minnesota station (*16*) failed to find as high as 60 per cent of the milk from infected cows to contain *B. abortus*, as has been reported by other investigators.

Pathogenicity of B. abortus.—Strains of *B. abortus* vary markedly in their pathogenicity, as shown by experiments with guinea pigs at the Minnesota station (*16*). Strains isolated from swine are apparently more pathogenic than those from cattle. Records of herds in Oregon (*35*) showed that the disease had apparently not lost its virulence in seven years. The Michigan station (*13*) isolated a number of nonvirulent strains and observed that a majority of them declined in virulence after cultivation for several generations on an artificial medium. There is no rule as to the length of time an aborting cow will carry each succeeding calf, according to the Kentucky station (*39*).

Resistance to infection.—That reacting calves apparently have the power to destroy the infection completely before reaching sexual maturity was indicated by investigations at the Missouri station (*37*). Unbred heifers did not become reinfected by continuous exposure to nonpregnant reacting cows. The mature female host apparently does not have the power to destroy readily and eliminate effectually *B. abortus*, but may remain a permanent carrier. In observations reported by the Connecticut Storrs station (*2*) calves exhibited at birth the same reaction as their dams, and after the sixth and up to the ninth or tenth months were nonreactors and presumably free from the infection. From the ninth to the tenth month was a period of unusual susceptibility to permanent infection. During this period and up to 3 years of age the greatest care is required to combat the spread of infection.

Mastitis and sterility.—There is much more mastitis in infected than in abortion-free cows, according to observations by the Oregon station (*11, 12*). Incurable sterility was shown by the Minnesota station (*28*) to be associated with certain streptococci combined with *B. pyogenes*, and occasionally colon bacilli and staphylococci were involved, *B. abortus* probably preparing the way for other organisms. A large percentage of aborting cows became sterile from closure of the os uteri by fibrous adhesions, usually in connection with a cystic condition of the ovaries, according to the Wyoming station (*42*). In some cases success in breeding followed the rupture of the cysts and breaking down of the adhesions of the os. According to the Wisconsin station (*22*), in the treatment of sterility the autogenous bacterin, if used, must be accompanied by irrigation of the uterus and cervix with a dilute disinfectant such as Lugol's solution, 1 to 400 of boiled water.

Control measures.—The method of eradicating abortion through testing herds, eliminating all reactors, and cleaning and disinfecting the barns has proved successful in case of individual herds in Oregon (*35*). A system of eradication similar to the Bang system of controlling tuberculosis is being tried out, and in one small herd with five reactors there was no spread of infection to sound animals in 15 months, the reacting cows breeding fairly well and calves being raised.

Success in controlling abortion in some herds by removal of the blood-serum reactors is based upon sound scientific data, according to the California station (*43*), and is to be recommended in herds where the infection is not too great. It was found that week-old calves drinking milk artificially infected with *B. abortus* discharged the organism in the feces, and thus may contaminate their surroundings. The blood of these artificially infected calves remained negative to the abortion agglutination test throughout the 37 days that they were fed the abortion organism.

Disinfection of the sheath of the bull and of the vulva and surrounding parts of the female before and after service and dairy barn sanitation are reported to have given good results in control of the disease at the Connecticut Storrs station (*29*). Administration of methylene blue was followed by a somewhat lowered percentage of abortion, in experiments at the Vermont station (*44*). The

disease was eliminated from a herd at the Connecticut Storrs station (*3*) in seven years by selling aborters promptly and by gradual disposal of old reacting cows, but inconclusive results were obtained from the feeding of methylene blue (*2*). Of the various disinfectants tested at the Connecticut Storrs station (*33*), cresol and lysol, which have the same disinfectant value, are preferred, the former being less expensive.

Immunity and immunization.—Abortion vaccine showed a decided immunizing value in experiments at the Wisconsin station (*22, 45, 46*), particularly for cattle of certain groups, such as open cows that had never aborted, and reduced trouble with retained placenta. Vaccinated cattle showed a decrease not only in the abortion rate but in the sterility rate as well. With open cows in infected herds that had never aborted, the vaccine was over 90 per cent effective, as contrasted to about 44 per cent in the control animals. Treating aborting cows with a vaccine gave encouraging results as a means of combating the disease. It is pointed out (*22*) that, since the vaccine is a preparation containing the living germs, it can be safely used only on unbred heifers and open cows at least two months before being bred. It is also stated that the abortion germs have never been known to live in the nonpregnant uterus longer than 58 days.

Negative results were obtained from administration of 20 cubic centimeters of a fresh vaccine prepared at the Indiana station (*47*) by growing *B. abortus* on agar flats for about two days, then washing the growth off with physiological salt solution.

The organism will live for at least two months in a vaccine prepared with a physiologic salt solution and stored in a refrigerator, according to the Wisconsin station (*25*). The Oklahoma station (*15*) found that vaccination may in many instances control the disease. A study of artificial immunity at the Minnesota station (*48*) showed that natural infection does not offer a reliable means for testing the immunizing value of biological agents.

A vaccination experiment at the California station (*49*) demonstrated definitely the protective value of live abortion germ vaccine in the prevention of abortion, and also the ability of *B. abortus* to furnish this protection when given to susceptible animals through the mouth at a single exposure.

The use of vaccine at the Michigan station (*50*) apparently resulted in a decrease in the abortion and sterility rate of the treated animals and a marked increase in the breeding efficiency of the treated over the untreated animals. It was also noted that calves born of treated animals gave negative reactions to the serological tests at birth and were not affected with white scours or other diseases attributed to *B. abortus*.

INFECTIOUS ABORTION OF SWINE

Prevalence.—Abortion has developed into a serious menace to the swine industry, particularly in Wisconsin, Minnesota, and Illinois (*36, 51, 52, 53*). In certain infected herds in Illinois as high as 30 to 40 per cent of the bred sows aborted in initial outbreaks of the disease. In an outbreak in California (*54*), 105 of 140 gilts aborted and none of 60 sows. It was found that *B. abortus* did not live in the normal nongravid uterus of gilts for more than two weeks after being introduced artificially, but persisted as long as four weeks when associated with pyogenic bacteria and the presence of a metritis. The number of abortions observed in herds in Kentucky (*55*) ranged from 5 to 100 per cent.

Relation to bovine abortion.—The Missouri station (*56*) showed that the organisms of bovine and porcine origin correspond in morphology, cultural characters, serological reactions, and pathogenic action on guinea pigs. This station found some experimental and clinical evidence of the susceptibility of swine to the bovine type. The Wisconsin station (*36, 53*) found that the organism of bovine origin did not cause pregnant sows to abort. In experiments at the Michigan station (*57*), pigs were subjected to natural infection by being kept in barn lots with cows known to be carriers and were also fed a suspension of abortion bacteria of bovine origin at periods of from 1 to 15 days without producing abortion. It is concluded that the feeding of infected milk or the association of swine with cattle infected with *B. abortus* should not be considered dangerous as far as the possibility of infecting swine is concerned. That station concludes, however, that infection and expulsion of the premature fetus will take place when an enormous dose of the bovine type is ingested and when swine are injected with living cultures of the

bovine type. In tests carried on over a period of three years, the Arkansas station (*58*) failed to transmit bovine infectious abortion to sows by feeding them milk from infected cows either before or after they became pregnant. Sows were even fed pure cultures of organisms from infected cows, and in no case was the disease transmitted to the sow. On the other hand, when the bovine virus was injected intravenously into sows, abortion resulted in a number of cases. The Illinois station (*51*) states that although it has not been established that swine contract the disease from infected cattle, it appears that cattle are susceptible to abortion bacilli found in swine, and that care should be taken to prevent the disease from being intercommunicated.

Detection.—Blood tests were found by the Wisconsin station (*36*) to be the most satisfactory means of detecting the disease in swine, the agglutination method being preferred.

Transmission and susceptibility.—In experiments at the Wisconsin station (*53*), infection was apparently contracted by ingesting abortion bacilli, but sows appeared to have considerable resistance against abortion bacilli introduced by way of the mouth before they were bred. Intravenous infection before breeding produced abortion in about 75 per cent of the cases under experiment. A boar injected intrapreputially was able to transmit the disease to sows which he covered shortly after receiving the inoculum. The Missouri station (*56*) concludes that nonpregnant as well as pregnant sows may contract the disease. The herd boar is susceptible and may contract the disease by association with infected sows, but whether by copulation or by ingestion has not been established.

The chief mode of transmission of the organism in swine, according to the Missouri station (*56*), is probably through ingestion by healthy pregnant sows of material contaminated with it by the reacting sow at the time of abortion or at the time of farrowing. This station (*59*) found that the minimum age of susceptibility of gilts to active infection with *B. abortus* corresponds closely to the advent of sexual maturity. The Wisconsin station (*53*) concludes that the disease is so much more likely to be introduced into a clean herd by purchase of swine from an infected herd than by feeding dairy products containing bovine abortion germs, that infection from cattle may be practically ignored. This station (*36*) found that the average time required for abortion to result after infection was about 23 days for the sow.

In experiments at the Illinois station (*23*), infectious abortion in swine was induced by the intravenous and subcutaneous injection of abortion bacilli, and also by feeding abortion bacilli isolated from cases of swine abortion. However, artificially infected sows did not abort consistently. The milk of some artificially infected sows was found to contain bacilli, but it is considered that these organisms do not survive in the nursing young to induce active abortion.

It is possible for some sows to become infected by way of the vagina after the uterine seal has formed, according to the Wisconsin station (*60*), but apparently infection by this path after conception has taken place does not occur frequently. Experimental gilts were infected by vaginal introduction of abortion bacilli before pregnancy. The establishment of infection in nonpregnant sows was found to be more difficult than in pregnant ones. Sows become infected most readily per vagina at or near the time of service. Most of the sows and gilts experimentally infected with living abortion bacilli failed to react to the agglutination test after the lapse of four months, indicating that the danger of establishing permanent infection carriers by vaccination is not great. After the subcutaneous and intravenous injection of living abortion bacilli a small percentage of sows and gilts failed to conceive even though served repeatedly.

Immunity.—Abortion in hogs is a self-limiting disease, in that a naturally acquired infection is usually followed by immunity, which will protect some sows for a long period of time, according to the Wisconsin station (*25*). Vaccination experiments at the station justify the belief that it is a means of conferring active immunity and promises to be effective as a means of control (*25*, *53*). Subcutaneous and intravenous injection of living abortion bacilli in open sows and gilts apparently resulted in no permanent injury in the majority of cases (*60*). This treatment enabled both open sows and gilts to withstand the effects of large doses of abortion germs after they were bred. The station finds that swine usually, though not always, react to the agglutination test following subcutaneous and intravenous injections of living abortion bacilli. Observations on a herd by the Kentucky station (*61*) indicate that swine do not become resistant

to abortion infection following one abortion as generally believed, but do become resistant after the second and third abortions.

In extended studies by the Missouri station (*59*) of the transmission of the complement-fixing *B. abortus* antibodies it was found to be an almost invariable rule that the blood samples of pigs from abortion-reacting dams were negative if drawn before pigs had sucked the mother and positive if drawn a while after the pigs had sucked. The reaction was of a positive nature, due to the ingestion of colostrum, and disappeared in the course of a few weeks, a minimum period of 18 days and a maximum period of 79 days, with an average of 45 days, having been observed. The age at which gilts exposed to maternal infection showed evidence of a durable positive serological reaction for the specific *B. abortus* antibodies varied from 4½ to 22½ months, the greater number from 6 to 9½ months of age. It was found that the antibody content of the blood fluctuated more in young than in mature swine that become infected, as shown by alternating positive and negative periods. Sexually mature sows, as a rule, retained the abortion infection indefinitely and reacted persistently to the serological tests.

In control work at the Kentucky station (*62*), in which three or four injections of bacterin were made, encouraging results were obtained, which, however, were not conclusive as to its value.

EQUINE INFECTIOUS ABORTION

Abortion in the mare has been investigated at the Kentucky, Minnesota, and Iowa stations. The first (*63*) found the trouble to be due to a member of the colon typhoid group distinct from that in cattle, to which the name *B. abortivo-equinus* was given. A number of Kentucky breeders have immunized their horses with a bacterin discovered and prepared by the station (*64*, *65*), and in no instance where it has been used as a prophylactic has the disease occurred. Several hundred mares have been immunized (*66*), with perfect results so far as could be determined, by four doses of the bacterin administered at intervals of seven days. The only apparent disadvantage of this treatment was a stiffness of the muscles in some cases (*64*) which lasted for a day or two.

The Minnesota station (*52*, *67*) concludes that hemolytic streptococci are the cause of nearly all the infections of breeding mares and foals in that State. Mares in foal were treated with an autogenous streptococcic bacterin at about the seventh month of pregnancy with very satisfactory results. A study of the action of eight strains of *B. abortivo-equinus* on certain of the carbohydrates has been reported by the Minnesota station (*68*).

The isolation from the foal of an aborting mare of an organism belonging to the abortion Malta fever group and which was apparently *B. abortus* is recorded by McNutt and Murray of the Iowa station (*69*).

ABORTION IN SHEEP

Abortion in sheep and goats is occasionally reported, but in the cases studied by the stations it appears to have been due to other causes than *B. abortus* and is essentially different from the common forms of infectious abortion. An outbreak of abortion among range sheep in Montana in 1923 was found by the station (*70*) to be due to the vibrio described by McFadyean and Stockman, the probable source of infection being a polluted water supply. The disease occurred in enzootic form. The agglutination test appeared to have definite diagnostic value for the disease.

REFERENCES

(1) Control of bovine infectious abortion. I. F. Huddleson. Mich. Sta. Quart Bul., vol. 5, No. 4, pp. 178-181. 1923.
(2) Infectious abortion in cattle. L. F. Rettger and G. C. White. Conn. Storrs Sta. Bul. 93. 1918.
(3) Infectious abortion in cattle.—Fourth report, Calving and blood reaction records of thirteen herds. G. C. White, L. F. Rettger, and L. M. Chapman. Conn. Storrs Sta. Bul. 112. 1923.
(4) Ark. Sta. Bul. 181 (Rpt. 1922), p. 66.
(5) Wyo. Sta. Rpt. 1922, p. 164.
(6) Abortion disease in Wyoming. C. Elder. Wyo. Sta. Circ. 18. 1922.
(7) Calif. Sta. Rpt. 1922, p. 164.
(8) Bovine infectious abortion and associated diseases of cattle and newborn calves.—II, The importance of *Bacterium abortum* of Bang and other microorganisms in bovine infectious abortion. J. Traum. Calif. Sta. Bul. 353, pp. 294-325. 1923.
(9) Kans. Sta. Bien. Rpt. 1921-22, p. 26.
(10) Colo. Sta. Rpt. 1922, p. 26.
(11) Oreg. Sta. Bien Rpt. 1921-22, p. 41.
(12) Infectious abortion of cattle. B. T. Simms and F. W. Miller. Oreg. Sta. Bul. 192. 1922.
(13) The comparative pathogenicity of several strains of *Bacterium abortus* (Bang). I. F. Huddleson. Mich. Sta. Tech. Bul. 55. 1922.
(14) Mo. Sta. Bul. 197 (Rpt. 1922), p. 91.
(15) Okla. Sta. Rpt. 1922, p. 25.
(16) Minn. Sta. Rpt. 1922, p. 108.

(17) A few notes on the isolation and cultivation of *Bacterium abortus*, with special reference to liver and spleen media. H. J. Stafseth. Mich. Sta. Tech. Bul. 49, pp. 7–11. 1920.
(18) The isolation of *Bacterium abortus* from milk. I. F. Huddleson. Mich. Sta. Tech. Bul. 49, pp. 25–30. 1920.
(19) The diagnosis of infectious abortion in cattle. F. M. Surface. Ky. Sta. Bul. 166. 1912.
(20) Ind. Sta. Rpt. 1923, p. 63.
(21) The diagnosis of contagious abortion in cattle by means of the complement fixation test. F. B. Hadley and B. A. Beach. Wis. Sta. Research Bul. 24. 1912.
(22) Contagious abortion questions answered. F. B. Hadley. Wis. Sta. Bul. 296, rev. 1921.
(23) Ill. Sta. Rpt. 1922, p. 18.
(24) On the possibility of differentiating between infected and immune animals in infectious abortion. H. J. Stafseth. Mich. Sta. Tech. Bul. 49, pp. 12–24. 1920.
(25) Wis. Sta. Bul. 352 (Rpt. 1922), p. 86.
(26) Wis. Sta. Bul. 362 (Rpt. 1923), p. 108.
(27) Oreg. Sta. Bien. Rpt. 1921–22, p. 39.
(28) Minn. Sta. Rpt. 1921, p. 83.
(29) Infectious abortion in cattle.—Third report. L. F. Rettger, G. C. White, and L. M. Chapman. Conn. Storrs Sta. Bul. 108. 1921.
(30) Mo. Sta. Bul. 210 (Rpt. 1923), p. 71.
(31) Calif. Sta. Rpt. 1923, p. 238.
(32) Mo. Sta. Bul. 197 (Rpt. 1922), p. 90.
(33) Infectious abortion in cattle.—II, Specific measures of control and ultimate eradication. G. C. White and L. F. Rettger. Conn. Storrs Sta. Bul. 103. 1919.
(34) Paths of infection by *Bacterium abortus* in rabbits, guinea pigs, and mice. E. S. Sanderson and L. F. Rettger. *In* Jour. Infect. Diseases, 32 (1923), No. 3, pp. 181–186.
(35) Oreg. Sta. Bien. Rpt. 1921–22, p. 40.
(36) Wis. Sta. Bul. 352 (Rpt. 1922), p. 85.
(37) Mo. Sta. Bul. 189 (Rpt. 1921), p. 57.
(38) Mo. Sta. Bul. 189 (Rpt. 1921), p. 58.
(39) Ky. Sta. Rpt. 1922, p. 44.
(40) The rôle of the udder and its secretion in bovine infectious abortion. W. Giltner, I. F. Huddleson, and R. L. Tweed. *In* Jour. Amer. Vet. Med. Assoc., 62 (1922), No. 2, pp. 172–178.
(41) Bovine infectious abortion and associated diseases of cattle and newborn calves.—I, Methods of controlling abortion. G. H. Hart. Calif. Sta. Bul. 353, pp. 271–293. 1923.
(42) Wyo. Sta. Rpt. 1921, p. 134.
(43) Calif. Sta. Rpt. 1923, p. 239.
(44) Concerning infectious abortion. F. A. Rich. Vt. St. Bul. 231. 1923.
(45) Wis. Sta. Bul. 339 (Rpt. 1921), p. 15.
(46) Wis. Sta. Bul. 362 (Rpt. 1923), p. 107.
(47) Ind. Sta. Rpt. 1923, p. 63.
(48) Minn. Sta. Rpt. 1922, p. 107.
(49) Calif. Sta. Rpt. 1923, p. 240.
(50) Studies in infectious abortion. I. F. Huddleson. *In* Jour. Amer. Vet. Med. Assoc., 58 (1921), No. 5, pp. 524–531.
(51) Infectious abortion in swine. Ill. Sta. Circ. 271. 1923.
(52) Minn. Sta. Rpt. 1921, p. 84.
(53) An experimental study of infectious abortion in swine. F. B. Hadley and B. A. Beach. Wis. Sta. Research Bul. 55. 1922.
(54) Calif. Sta. Rpt. 1922, p. 165.
(55) Ky. Sta. Rpt. 1922, p. 47.
(56) Infectious abortion in swine. J. W. Connaway, A. J. Durant, and H. G. Newman. Mo. Sta. Bul. 187. 1921.
(57) Further studies on the susceptibility of swine to bovine infectious abortion. I. F. Huddleson. Mich. Sta. Quart. Bul., vol. 6, No. 1, pp. 25–28. 1923.
(58) Ark. Sta. Bul. 181 (Rpt. 1922), p. 68.
(59) Mo. Sta. Bul. 197 (Rpt. 1922), p. 94.
(60) Wis. Sta. Bul. 362 (Rpt. 1923), p. 105.
(61) Ky. Sta. Rpt. 1922, p. 49.
(62) Ky. Sta. Rpt. 1922, p. 48.
(63) Further investigations of the etiology and control of infectious abortion in mares. E. S. Good and W. V. Smith. Ky. Sta. Bul. 204. 1916.
(64) Ky. Sta. Rpt. 1921, p. 27.
(65) The control of infectious abortion in mares. E. S. Good. *In* Vet. Med., 16 (1921), pp. 23, 24.
(66) Ky. Sta. Rpt. 1922, p. 45.
(67) Minn. Sta. Rpt. 1922, p. 110.
(68) A study of the action of eight strains of *Bacterium abortivo-equinus* on certain of the carbohydrates. C. P. Fitch and W. A. Billings. *In* Jour. Bact., 5 (1920), pp. 469–476.
(69) *Bacterium abortum* (Bang), isolated from the fetus of an aborting mare. S. H. McNutt and C. Murray. *In* Jour. Amer. Vet. Med. Assoc., 65 (1924), No. 2, pp. 215, 216.
(70) Vibrionic abortion in sheep. H. Welch and H. Marsh. *In* Jour. Amer. Vet. Med. Assoc., 65 (1924), No. 2, pp. 203–210.

HISTORY OF STATION WORK IN AGRICULTURAL ECONOMICS

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In connection with the ninth annual meeting of the American Economic Association at Baltimore, Md., in 1897, there was a discussion by such leaders in agricultural, economic, and sociological thought as W. A. Scott, C. S. Walker, L. F. Ward, E. R. A. Seligman, and others of the economic phases of land tenure, mortgage indebtedness and credit, and the movement of population from the farm to the city (*1*).[2] The discussion did not give particular attention to the economics of farm management or of marketing but rather to the maladjustment of agriculture with other industries. This meeting constituted what was probably the first public attention given in the United States to agricultural economics, and its general purpose was to answer the question, "Is there a distinct agricultural question?" This was answered by some of the speakers in the affirmative, by others in the negative. It persisted, however, and in 1903 the subject was again recognized, this time in a joint session held between Section I of the Association for the Advancement of Science and the Society for the Promotion of Agricultural Science (*2*). Among the papers read were Improvement in Farm Management, by W. M. Hays; Economic Functions of Livestock, by C. F. Curtiss; Agricultural Economics, by H. C. Taylor; and The Evolution of Agriculture in the Middle West and Its Social and Economic Significance, by E. Davenport.

In December, 1906, the committee on methods of teaching agriculture of the Association of American Agricultural Colleges and Experiment Stations, in outlining a 4-year college course in agriculture, drew up and published a syllabus of a course in rural economics. In this, rural economics is defined as that subject which treats of agriculture as a means for the production, preservation, and distribution of wealth by the use of land for the growing of plants and animals. It includes the development of agriculture as a business (history of agriculture), as well as the facts and principles of farm management under present conditions (*3*).

In 1907 the first round table on agricultural economics was held during the annual meeting of the American Economic Association under the chairmanship of T. N. Carver (*4*). Those present and participating in the discussion at this time included men interested in the subject from the standpoint of farm management and country life, as well as those who had approached it more largely from the academic field of economics. It was pointed out that the teaching of economic science at the land-grant colleges had been specifically provided for in the second Morrill Act of 1890 (*5*).

At the fourth session of the Graduate School of Agriculture, held at the Iowa State College, Ames, Iowa, July 4–29, 1910, the initial discussion of the field of teaching and investigation in farm management and rural economics and sociology was successfully undertaken, and the American Farm Management Association, now the American Farm Economic Association, was formed, with W. J. Spillman, president; D. H. Otis, vice president; and G. F. Warren, secretary-treasurer (*6*).

Meanwhile research along these lines had been begun, and in this connection it is interesting to recall the remarks of Professor Scott at the meeting in 1897 mentioned above, when he noted the almost complete absence of definite information upon which to base an answer to the question which had been propounded. He stated that in order to inform himself upon actual agricultural conditions he had endeavored to collect accurate information regarding two small sections, one a township in western New York and the other a township in southern Wisconsin. This effort on his part may be regarded as a forerunner of the numerous surveys which have been made in more recent years.

[2] Numbers in parentheses refer to references page 86.

Some historical interest attaches to the fact that estimates of the cost of raising corn, cotton, and other crops appear in reports of the commissioners of agriculture as early as 1849 and 1850. The cost of cultivating and husking 20 acres of corn in Madison County, Ill., was reported in 1870, and estimates for small acreages in Indiana, Ohio, Pennsylvania, and New York are given in the following year. Prompted by inquiries relative to the cost of raising cereals, the United States Department of Agriculture instituted an inquiry covering the average and total cost under several items for individual States, groups of States, and the country as a whole; and a report based on the estimates made by over 28,000 practical farmers, checked by replies received from over 4,000 experts, was published by the division of statistics (*7*). Nebraska station in 1893 published a bulletin on the cost of farm crops in eight fields at the station (*8*). This presented three tables showing the yield and cost per acre of wheat, oats, and rye, corn, and hay, as well as the cost of marketing and the price per bushel on the Lincoln, Nebr., market, the profit per bushel and per acre, and the rate of interest paid on a land valuation of $25 per acre, omitting taxes. N. A. Weston, then a graduate student of economics at the University of Illinois, undertook an inquiry into the cost of raising corn and oats in Illinois in the season of 1896, and a bulletin was published in 1898 (*9*). In this investigation actual expenditures in terms of day labor wherever possible were asked for, as well as the rate of wages per man and per man and team. Over 300 returns were received in reply to the questionnaires sent out to farmers, 274 of which were used in constructing the tables for corn and 170 for oats.

W. M. Hays, of the Minnesota station, was the initiator of actual systematic and sustained field studies in agricultural economics and therefore the pioneer in research along this line. As early as 1894 he was giving his students exercises in the mapping of their own home farms and subsequently planning readjustments and improvements in accordance with the principles of farm management which they had been learning. That he was active in initiating practical cost-accounting studies is evidenced in the report of the Minnesota Agricultural Experiment Station for 1902, where it is noted that—

"On January 1, 1902, this division [agriculture] and the Division of Statistics of the U. S. Department of Agriculture began a cooperative effort to secure data on the cost of growing field crops. Three statisticians were employed for the entire calendar year of 1902: One in southeastern Minnesota, near Northfield; one in southwestern Minnesota, near Marshall; and one in northwestern Minnesota, near Halstad, each with a route about 15 miles long, reaching 12 to 15 farmers. The statistician visited each farmer daily, and recorded where each portion of labor was used. The man hour was taken as the unit and the horse hour as half a unit. Young men suitable for this work were found in the college of agriculture, and very good results have so far been secured. These data will make it possible to make much better application of the results of the field experiments in farm management at the several experiment farms. The data thus gathered, together with the results of experiments in crop rotation by means of field plots added to the pedagogical methods worked out in teaching field management, are demonstrating the value of a union between the experiment station and the college of agriculture. The fact that the farming business can be reduced to a system which may be brought under pedagogical forms and taught in schools of agriculture is a point well worth the expense of demonstration. Many of the young men in the school of agriculture make farm plans as a part of their class work, often remodeling the arrangement of their home farms, which they afterwards report as having been adopted and put into operation at home. The experimental work of the station and the work of the classroom have developed the fact that orderly arrangement may be easily introduced on farms where a wrong system prevails" (*10*).

From simply collecting data on the cost of growing field crops the work developed to include gathering facts concerning produce marketing and the general profits of the entire farm enterprise. In the annual report for 1903–4 it was announced that a bulletin would be published giving the results of investigations in farm statistics and describing the methods developed and the data secured by the three men working in the three areas noted. This made its appearance in October, 1906 (*11*), the first station bulletin to appear in the then com-

paratively new section dealing with the subject of rural economics.

Professor Hays having been appointed in January, 1905, to the position of Assistant Secretary of Agriculture, the division of agriculture at the Minnesota station was somewhat reorganized and the pioneer in agricultural cost accounting in this country carried his work into larger fields, becoming directly responsible for the cost of production studies begun by the United States Department of Agriculture. Cost-accounting routes have been maintained continuously in Minnesota up to the present time with the exception of the years 1918 and 1919 when war conditions necessitated their temporary suspension. The work was renewed January 1, 1920, and two routes of 24 farms each are now being maintained in cooperation with the Bureau of Agricultural Economics, United States Department of Agriculture. This type of work has been adopted from time to time in various parts of the country, until at present 20 States are conducting detailed cost studies either independently or in cooperation with the Bureau of Agricultural Economics (*12*).

Two other stations that have been leaders in research in farm management and agricultural economics are Wisconsin and New York Cornell. In June, 1903, an apple orchard survey in Wayne County, N. Y. (*13*), was begun under the direction of J. Craig by G. F. Warren, then a fellow in agriculture. This was followed by similar studies in other counties in New York, and in May, 1905, an apple orchard survey of Orleans County (*14*) was published. Subsequently, the name of G. F. Warren appeared on the staff of the New York Cornell station, and in his list of cooperative experiments in agronomy in the director's report for 1906, he includes two of an economic nature, the cost and profit or loss in producing crops and the reduction of labor by the use of more horses per man.

In the report of the New York Cornell station for 1908 it is maintained that "the greatest immediate returns for the money invested in this department are secured from the survey work directed (1) to the study of specific crops and (2) to the study of farming as a business" (*15*). The most important work along this line in that year was the agricultural survey of Tompkins County, N. Y. (*16*), of which the field work was practically completed at the time of submitting the report. This survey was actually begun in 1906, and information was collected with regard to a large number of points. The aim of the work was changed in 1907 to that of a farm-management survey to determine the profits for the year on each farm and to find what conditions and types of farms resulted in the largest profit or labor income. The statistics that were finally published, however, were for 1908, because it was not until that year that methods of procedure were so perfected that satisfactory results were obtained. The Tompkins County survey may well be regarded as an epoch-marking contribution to the country-life movement. It was indeed a complete census taking and the first of surveys using statistical methods which had been recommended in the report of President Roosevelt's country life commission in December, 1908.

The report for the year ended September 30, 1908, notes that among other pieces of research work that had been conducted by students and which were worthy of publication was one with reference to the incomes of 194 New York farmers carried on by M. C. Burritt. This study was published in December, 1909 (*17*).

It was not until 1909 that the staff of the Wisconsin Agricultural Experiment Station included a worker in agricultural economics. In the director's report for 1908–9 it is reported that a comparatively new but promising line of inquiry would be organized for the ensuing year, namely, a department of agricultural economics. (*18*). H. C. Taylor, who had been engaged in economic research along agricultural lines in the university, was chosen to head this department, and his work was transferred to the college of agriculture and experiment station. The first bulletin to be published appeared in July, 1910 (*19*). The aims of the various lines of investigation outlined by the new department were the gaining of knowledge of economic forces which influence the farmer in determining what to produce; the kinds and qualities of land, labor, and equipment to use; the degree of intensity of cultivation; the size of the farm; systems of tenure; credit; methods of marketing; and other problems.

The following year it was reported that cost accounting had been successfully carried forward on 15 Wisconsin farms under the supervision of the agricultural economics department of the station in cooperation with the division of farm management of the Bureau of Plant Industry, United States Department of Agriculture. This accounting included an

inventory, financial statement, and man and horse-labor records. Its purpose was to give the farmer a record of the year's operations and of the profits of his business, and also a complete statement of labor and other costs and the results of each line of production which would show him in detail the sources of his profits and losses. It was attempted to indicate the relative profitableness of various competing crops, such as corn, tobacco, and sugar beets, or barley, oats, and spring wheat (*20*).

By 1910 historical and geographical studies were well established and studies of land tenure were being continued with special reference to negro tenure and plantation organization in the Cotton Belt. Farm surveys were being made by D. H. Otis, of the Wisconsin experiment station, who was personally visiting large numbers of farms to secure data with regard to good and bad farm-management practices associated with various types of farming. In the next year, work in cost accounting was begun in cooperation with the Office of Farm Management of the United States Department of Agriculture; also, Professor Otis had gathered data on 103 Wisconsin farms as to the capital in use and the distribution, amount, and sources of farm income and expenditures. Prominent leaders have been developed at this institution in later years in other important phases of the broad subject of agricultural economics, particularly cooperation among farmers and the marketing of agricultural products.

Survey and cost-accounting work has been carried on consistently, once it was fairly outlined and its importance realized, and notable progress has been made. Definitions of and agreement as to terms and the proper interpretation and application of data are problems demanding considerable attention at the present time.

Cooperation with the U. S. Department of Agriculture has greatly strengthened, coordinated, and extended the economic work of the individual stations. Charts prepared by the Bureau of Agricultural Economics, indicating all the regions which had been surveyed in the United States or were represented in published reports of field studies up to and including 1922, show that one or more sections in every State with the possible exception of Nevada, Wyoming, and Tennessee have been the subject of more or less intensive, statistical, analytical study with reference to the economics of some phase or phases of their agriculture (*21*).

In the classified list of projects carried on by the experiment stations, 1922–23, there are listed 186 projects in rural economics. These are arranged under the heads of cost of production and accounting, farm labor, farm organization and management, farmers' cooperative organizations, land settlement, land tenure, land values, marketing, rural credit, rural sociology, and miscellaneous studies. In this list, 37 States are represented by at least one project, while certain States, as Minnesota, Iowa, and New York, report from 12 to 28. Under cost of production and accounting are found 63 and under farm organization and management 36 projects.

These numbers indicate the importance given by the leaders in investigation to the gathering of specific data of a type useful in planning the farm organization, particularly in the choice and combination of enterprises and in increasing efficiency in the conduct of individual enterprises. It is to be expected that more and better economic studies will be carried on along these lines, leading to well-advised programs of action in the adjustment of the individual farming business to changing economic conditions, to better organization among farmers for marketing and distribution, and to furthering economic legislation affecting agriculture.

REFERENCES

(1) Amer. Econ. Assoc. Sup. Econ. Studies, 2 (1897), pp. 52–67.
(2) The development of the American Farm Economic Association. H. C. Taylor. *In* Jour. Farm Econ., 4 (1922), p. 67.
(3) U. S. Dept. Agr., Off. Expt. Stas. Circ. 69 (1906), pp. 18, 19.
(4) Papers and discussions of the twentieth annual meeting, Dec. 28–31. *In* Amer. Econ. Assoc. Quart., 3. ser., 9 (1908), pp. 59–82.
(5) U. S. Dept. Agr., Dept. Circ. 251 (1923), p. 4.
(6) Expt. Sta. Rec., 23 (1910), pp. 406, 407.
(7) U. S. Dept. Agr. Rpt. Sec., 1893, pp. 513–518.
(8) Cost of farm crops. C. L. Ingersoll and S. W. Perin. Nebr. Sta. Bul. 29. 1893.
(9) The cost of production of corn and oats in Illinois in 1896. N. A. Weston. Ill. Sta. Bul. 50. 1898.
(10) Minn. Sta. Rpt. 1902, pp. VII, VIII.
(11) The cost of producing farm products. W. M. Hays and E. C. Parker. Minn. Sta. Bul. 97. 1906.
(12) The use of detailed cost studies in improving farm organization in a community. G. A. Pond. *In* Jour. Farm Econ., 6 (1924), p. 69.

(13) An apple orchard survey of Wayne County, N. Y.—I, The apple industry. G. F. Warren. N. Y. Cornell Sta. Bul. 226. 1905.
(14) An apple orchard survey of Orleans County. G. F. Warren. N. Y. Cornell Sta. Bul. 229. 1905.
(15) N. Y. Cornell Sta. Rpt. 1908, p. V.
(16) An agricultural survey: Townships of Ithaca, Dryden, Danby, and Lansing, Tompkins County, N. Y. G. F. Warren, K. C. Livermore, et al. N. Y. Cornell Sta. Bul. 295. 1911.
(17) The incomes of 178 New York farms. M. C. Burritt. N. Y. Cornell Sta. Bul. 271. 1909.
(18) Wis. Sta. Bul. 193 (Report of Director, 1909), p. 11.
(19) Methods of renting farm lands in Wisconsin. H. C. Taylor. Wis. Sta. Bul. 198. 1910.
(20) Wis. Sta. Bul. 203 (Report of Director, 1910), p. 23.
(21) Farm management extension: Early development, and status in 1922. H. M. Dixon. U. S. Dept. Agr., Dept. Circ. 302 (1924), pp. 7, 10.

STATION WORK ON THE VENTILATION OF ANIMAL SHELTERS

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Considerable interest has developed ecently, particularly in the Central, orthern, and Northwestern States, in ecuring a broader and more fundaiental knowledge of the ventilation ot only of beef-cattle, dairy-cow, heep, and horse barns, but also of og and poultry houses. There are bout nine projects either in operation r being planned at as many State exeriment stations on one phase or anther of the subject or on some closely elated subject. There is evidence of n effort to get away from the mere omparative testing of ventilating ontrivances and to establish some of ne principles governing the operation f such equipment as a basis for its erfection.

The lack of fundamental knowledge f the subject is reflected in the ather scattered record of work conucted by the experiment stations and y foreign institutions, extending back ver a period of from 35 to 40 years. s a whole, however, this work indiates clearly the main purpose of venilation in animal shelters, viz, to suply sufficient fresh air, and to mainain such degrees of air purity, temerature, humidity, and exposure to raft as will provide for the particur animal concerned optimum condiions of health, comfort, and ecoomical production.

The more recent studies have shown n effort to attain a higher degree of cientific accuracy by basing judgment s to the condition of the animal conerned upon expert observations of uch factors as weight, body temperaure, blood circulation, respiration and etabolism, heat and carbon dioxide mission, rate of growth, activity, food nd water consumption, and apparent omfort, as well as egg production and uality in the case of poultry, milk roduction and quality in the case of airy cows, and meat production and uality in the case of beef cattle, hogs, nd sheep.

AIR SUPPLY AND PURITY

Livestock.—In studies of ventilation actors at the Wisconsin station, King *1*)[3] showed that the yield of milk, in two experiments with 20 and 25 cows, respectively, was larger in the periods of good ventilation of the dairy barn than in periods of poor ventilation, although there was no appreciable influence upon the quantity of food consumed. In experiments at the Maryland station, Buckley (*2*) demonstrated that the milk records of cows kept in a well-ventilated stable showed a decided increase in yield and that exposure to low temperatures did not necessarily reduce the yield as long as they were natural and constant.

In further studies at the Wisconsin station, King (*3*) found that in order to maintain health and comfort standards, a horse must draw into and force out of his lungs an average of 142 cubic feet of air per hour, a cow 117, a pig about 46, and a sheep about 30. He estimated that the necessary degree of freedom of the air from other gases was not less than 96.7 per cent. Since carbon dioxide produced by the animals in their metabolic processes is the gas most usually occurring in appreciable quantities in air under such circumstances, it was therefore used as an indicator of air purity apparently without reference to its effect other than as a displacer of air. From these figures and from figures obtained for the carbon dioxide contents of pure and expired air it was determined that on an average air must enter and leave a stable at the rate of 4,303 cubic feet per hour for a horse, 3,545 for a cow, 1,394 for a hog, and 909 for a sheep. Using the same basis of air purity, Armsby and Kriss (*4*) found in more controlled studies at the Pennsylvania station that a horse requires 2.307, a cow 3.452, a hog 767, and a sheep 332 cubic feet of air per hour. The figures for cows agree fairly well with those found by King, but those for the other animals vary widely. A very general disagreement also exists between these results and those found by certain foreign investigators.

Determinations of the carbon dioxide content of the air in the dairy barn at the New Hampshire station, made by Hendry and Johnson (*5*) showed that the percentages found at regular intervals during the day and night at 15 different locations in the

[3] Numbers in parentheses refer to referices, page 95.

front and rear of the animals varied from 0.228 to 0.089. It is to be noted that the percentages found by the 1918 Farm Building Ventilation Committee of the American Society of Agricultural Engineers (*6*), in studies of five barns, were as high as 1.231 but for the most part were not higher than from 0.2 to 0.3. The importance of a controlled study to determine proper carbon dioxide limits to correspond to the optimum health and comfort of these animals is thus plainly evident.

Poultry.—Apparently few data are available from the experiment stations on the requirements of poultry as regards the supply and purity of air. It may be noted, however, that Mackenzie and Russell (7) found, in controlled studies at the Southeastern Agricultural College, Wye, England, that chickens breathe about a pint of air per minute or 1.2 cubic feet per hour. Further studies (*8*) showed that, although poultry were apparently healthy in the presence of from 6 to 8 volumes of carbon dioxide in 10,000 of air, 9 volumes of carbon dioxide is the maximum permissible air displacement. From this it was estimated that each bird requires 40 cubic feet of air per hour to prevent exceeding this limit of purity and provide a satisfactory factor of safety.

HUMIDITY CONTENT AND TEMPERATURE OF AIR

Where natural systems of ventilation are used, the body heat given off by animals is relied upon to maintain the temperature of the stable or other shelter at a comfortable degree, especially in cold weather, and it also serves as the motive power for ventilation through its control of the air temperature.

Livestock.—Armsby and Kriss (*4*) showed at the Pennsylvania station that the bodies of farm animals during health maintain a nearly constant temperature as the resultant of thermogenesis and of thermolysis principally by radiation and conduction and as latent heat of water vapor. Although the external temperature tends to influence the outflow of bodily heat, the animal is able to regulate it by physical and chemical methods, but there is a certain critical external temperature at which the outflow of heat just balances the necessary heat production of the animal as a result of internal work. Above this temperature the radiating capacity of the body surface varies to meet the varying conditions. Below it, oxidation of tissue is required to maintain the normal temperature of the body. Thus temperature obviously influences feed consumption, productive feeding, and animal comfort.

In experiments at the Wisconsin station King (*1*) found a difference of 6.3° F. in the mean temperature of a dairy stable during periods of good and poor ventilation, and that the cows drank more water during the periods of poor ventilation. In studies at the Massachusetts station with six cows divided into two lots, Brooks (*9*) showed that the apparent influence of a warm stable upon milk and butterfat production was small, although on the average more milk and butterfat were produced in the warm stable. The most certain effect was the lowering of the percentage of the fat in the milk produced in the warm stable. The total increased product did not pay for artificial heating up to 55° F., but the artificial maintenance of a moderate temperature improved ventilation conditions and promoted the comfort of the animals.

In two trials with 12 cows and two with 6 cows conducted in different years at the Wisconsin station by Richards and Jordan (*10*), in which the effect of a stable temperature of about 55° F. was compared with that of one of about 45° upon the milk yield, it was found that on the average all the trials were in favor of the higher temperature. However, in one out of four trials there was a difference in milk yield and in another case a difference in fat content in favor of the lower temperature.

Clarkson and Whitnah (*11*) of the 1920 Barn Ventilation Committee of the American Society of Agricultural Engineers found, in studies of climatic dairy barns, that dairy barn temperatures may vary from 35° to 50° F., according to the climatic zone, but that they should never go below 33°. It was also found that the amount of heat given off by a dairy herd is very nearly constant for cattle of a given size for a given climate.

Armsby, Fries, and Braman (*12*) in studies at the Pennsylvania station established definite relations between the heat produced and carbon dioxide eliminated by cattle and derived mathematical expressions therefor. A comparison of the daily output of carbon dioxide and the heat production by steers and cows for 188 separate days showed that in each case the ratio of the carbon dioxide produced in grams to the total heat emission in calories was very close to 0.4. Armsby and Kriss (*4*) showed that the motive

power for ventilation derived from water vapor is of only secondary importance. They showed further that cows, horses, swine, and sheep of respective average live weights of 1,075, 1,250, 280, and 91 pounds will maintain respective average temperature differences corresponding to air flows computed from carbon dioxide production of 36.58, 36.49, 36.4, and 36.5° F. It is to be noted that the respective temperature differences as computed on the basis of the King standard (*1*) are 35.6, 19.6, 20, and 13.3° F.

Data on the temperature of the stable when air enters at different temperatures showed that when the King standard of air flow is taken as the minimum, the heat supplied by cows appears to become deficient for maintaining what is believed to be the best stable temperature when that outside is below 15° F. The heat supplied by horses, swine, and sheep appears to become deficient at a much higher outside temperature. However, when rate of air flow computed from the carbon dioxide production is made the basis of the computation the differences between the species disappear. Data on the maximum ventilation compatible with the maintenance of a given temperature difference indicated the necessity in severe weather of restricting the ventilation in order to conserve heat and maintain a desirable stable temperature. This was found to result in lowering the purity of the stable air below King's standard. In spite of the fact that the amount of carbon dioxide produced by animals is approximately proportional to their heat production, it was found that the accepted ventilation requirements for different animals are not proportional to their heat production. These results indicate clearly the need for further fundamental and controlled investigations of the temperature, humidity, and air purity requirements of cattle, horses, swine, and sheep, especially in view of the disagreement of many foreign investigators with some of these results.

Poultry.—In feeding experiments with 46 chickens at the North Dakota station, Hinebauch (*13*) showed that when the poultry house was heated about half as much food was consumed and the egg production was more than doubled. The results of two years' experiments at the West Virginia station by Stewart and Atwood (*14*) with floored and unfloored poultry houses showed that the fowls remained in as healthy a condition and laid as many or more eggs in the somewhat warmer unfloored houses as in the floored houses. Studies by Gardiner (*15*) at the Montana station showed that poultry houses may be profitably heated, an average temperature of from 45 to 50° F. being regarded as most satisfactory.

Somewhat in contrast to the above results, Kempster (*16*) found in two years' studies at the Michigan station with three flocks of 70 White Leghorn hens that there was nothing to be gained in egg production by the construction of warmer poultry houses. Opperman (*17*) found in experiments at the Maryland station that fowls kept in colder and less expensive houses gave as high returns as those confined in warmer and more expensive buildings. The general health of the fowls in the different buildings was practically the same during a period of two years, except that the lack of fresh air and the excessive moisture in the warm, tight house caused an absence of bright red combs and the appearance of rough and dirty plumage. The plumage of the fowls in the colder but better ventilated and drier houses was bright and clean.

These results show how investigators disagree regarding the temperature and humidity requirements of poultry and indicate a need for studies of these ventilation factors under controlled conditions.

MECHANICS OF VENTILATION

In spite of the obvious lack of accurate fundamental knowledge regarding the ventilation requirements of farm livestock and poultry, considerable work has been done at the experiment stations and other institutions on the mechanics of ventilation systems for specific purposes.

In this work the best possible use has apparently been made of the admittedly inadequate basic data available in an attempt to develop ventilation systems specifically adapted to the requirements of the animals as far as these were known.

Livestock shelters.—On the basis of his studies at the Wisconsin station of the ventilation requirements of livestock, King developed a system of ventilation for livestock shelters which was very generally adopted for a number of years. This system was incorporated in the new dairy barn at the station by Carlyle (*18*). It comprised a single ventilating flue rising above the roof of the main barn and divided below the roof into two arms terminating near the level of the stable

floor. These openings were provided with ordinary registers with valves to be opened and closed when desired. Other ventilators were available for temperature regulation. This system was also incorporated in the barns of several of the stations in original or modified form (*19*, *20*, *21*, *22*).

More recently it has been found that climatic and other conditions, as well as animal requirements, have considerable influence upon the type of ventilation system best adapted to a given purpose. The extreme variations in these have led to material modification of the King system and to the development of new systems, particularly in some of the neighboring Canadian Provinces.

For example, Reynolds (*23*), in experiments at the Ontario Agricultural College, developed a system of ventilation of stables by means of pipes extending to the floor of the stable and terminating at the peak of the roof in revolving cowls. The pipes were so arranged that the air entered for the most part at the floor in front of the stalls, and the foul air passed out by means of pipes leading from the ceiling of the stable to the barn roof.

Experiments by Grisdale at the Canada Experimental Farms (*24*) demonstrated the superiority of the so-called Rutherford system of stable ventilation, the essential feature of which is an arrangement whereby fresh air enters at the floor level and leaves through a flue extending from the ceiling to the roof. A modification of the King system also proved satisfactory. Experiments with the covering of stable windows with muslin when the outside temperature varied from 2° to 36° F. and the inside from 36° to 62° were unsuccessful, owing to the extreme range of resulting inside temperatures and the dampness of the air. Comparative tests conducted by Day (*25*) at the Ontario Agricultural College on muslin-curtain ventilation, the King, and the so-called Massey systems, showed that the muslin-curtain system is unreliable and inferior to either of the other systems, especially in view of the irregular distribution of carbon dioxide and moisture. The Massey system is based upon the same general principle as the Rutherford system, but varies in structural detail. Further studies by Grisdale and Archibald (*26*) at the Canada Experimental Farms demonstrated the superiority of the Rutherford system over the King system for horse and cow stalls and hog houses. Smith (*27*) obtained similar results in studies at the Manitoba Agricultural College and concluded that the Rutherford system is superior to all others for Canadian Northwest conditions. However, further studies by Smith (*28*) showed that either the King or Rutherford system can be used in banked barns or in barns having stone, brick, or concrete walls, but that the cubic space allowed should be less than 600 cubic feet per animal for cattle and less than 750 cubic feet per animal for horses.

Studies on climatic dairy barns by Clarkson and Whitnah (*11*) showed that a barn ventilating system makes the most efficient use of the heat given off by cattle by drawing the foul air from near the floor. The necessity was demonstrated of so constructing the walls that the heat losses through them will be small enough to leave the heat required for proper ventilation. Barn walls in the first climatic zone, where temperatures will drop as low as —30° F., should have a coefficient of heat loss not greater than 16 B. t. u. per hour per degree difference in temperature.

Experiments by Smith (*29*) at the Brandon Experiment Station in Manitoba showed that an average ventilation of 4,590 cubic feet per hour per cow obtained by the Rutherford system in a barn containing 67 cows and allowing 700 cubic feet of space per cow and 120 cubic feet of air to be breathed per hour per cow gave an air purity of 97.36 per cent. Decreasing the outtake flue area decreased the temperature fall inside as the outside temperature fell steadily, and finally caused an increase in the inside temperature without lowering the air purity below 95 per cent.

Experiments by Clarkson and Whitnah (*30*) on the proper relations between heat, light, and ventilation in hog houses showed that heat losses under first climatic zone conditions were least from (1) a 2-story building with overhead storage, (2) a 1-story building with a flat pitch gambrel roof and a ceiling extending across from one hip of the roof to the other, and (3) a 1-story building with a flat pitch gambrel roof and an inclined ceiling on each side extending from the hip of the roof down to the girders and across between the girders. The greatest heat losses occurred from a full monitor roof type and a shed roof type. Heat losses were also greater through skylights than through vertical windows.

Patty of the South Dakota station (*31*), found that, with over 1,200 cubic feet of air circulating through a hog house 80 by 28 feet in size and with low side walls and low overhead space, the air was changed completely every 16 minutes; but the temperature remained practically constant, although the outside temperature dropped from 4° to 5°. There was no excess moisture in the air, and the suction effect of the aerators on top was not necessary to maintain air circulation.

In studies of the factors influencing the operation of dairy barn ventilation systems, with particular reference to forced draft, Kelley (*32*) of the U. S. Department of Agriculture showed that, on the basis of the data obtained by Armsby (*4*) for dairy cows, as the total heat lost by ventilation and radiation decreased the temperature inside increased. On the basis of the heat production estimated from the individual weight of each cow, the results showed that with the fan system of ventilation used 43.7 per cent of the heat generated by the animals was lost by ventilation and 23.5 per cent by radiation.

In considering the design of outtake flues for dairy barn ventilation with a natural draft system on the basis of the heat and carbon dioxide production of dairy cows, Strahan (*33*), of the Massachusetts station, showed that different breeds of dairy cows introduced different conditions to be met. It was considered reasonable to expect Holsteins to maintain in zero weather a temperature above freezing in a stable 36 by 80 feet inside and housing 40 cows, and at the same time to maintain adequate ventilation conditions. On the other hand, it was shown that, if Jerseys in low production are housed, the stable temperature will drop below 32° F. as soon as the outside temperature goes below 6°, if the same rate of air flow is maintained through the stable. Under these conditions the air flow would have to be reduced over 1,200 cubic feet per cow in order to keep the inside temperature up, which would tend to lower the ventilation standard considerably. It was further shown that small Jersey cows on maintenance alone can maintain a temperature difference of from 15° to 17° in well-constructed stables, and it was considered correct to assume that outtake flues may be designed to pass the required amount of air through a stable at a minimum temperature difference of 20°. Armsby (*4*) also brought out that different breeds of dairy cows produce different amounts of carbon dioxide and heat.

In further studies in cooperation with several of the experiment stations, Kelley (*34*) showed that the factors influencing the maintenance of the desired temperatures in animal shelters are insulation, tightness of construction, air space each animal is expected to heat, and the desired amount of ventilation in accordance with the type of animal housed. No definite relation was established between the velocity of the wind and the effect which it has in the production of draft in a well-designed ventilating system. It was noted that in barns using wall intakes the wind sometimes had a greater influence upon the air going out than upon that coming in. The design and position of the intakes were found to influence back drafting and its velocity. The lowest wind velocity which produced back drafting in wall intakes 5 feet or more in length was 6 miles per hour. Window intakes were unreliable, made the control of the stable temperatures difficult, and permitted the wind velocity to exert a greater influence upon the amount of ventilation.

Under average conditions a greater difference was found between the ceiling and floor temperatures in horse stables than in dairy stables. Openings near the floor in outtakes appeared more favorable to the maintenance of stable temperatures than ceiling openings, especially during cold weather.

In further studies of hog-house ventilation conducted at several of the experiment stations (*35*), Kelley showed the possibility of maintaining a reasonably uniform temperature in a barn housing a total weight of 26,775 pounds of hogs by regulating the amount of intake openings.

Poultry houses.—Almost every experiment station has conducted a study of one or more phases of the poultry-house question. However, few have made a comprehensive study of the construction of poultry houses based upon the ventilation requirements of the poultry. There are a few exceptions to this, although practically no work of an entirely controlled nature is on record.

In experiments at the New Jersey stations, Lewis and Clark (*36*) showed that, under New Jersey conditions, a poultry house with a large area of glass and no muslin had a high moisture content and low temperature accompanied by rapid changes, whereas

an open-front house furnished ideal ventilation conditions, provided the birds were protected from rain, snow, and drafts. It was possible, however, to use some glass and muslin in the front. Provision of ample ventilation for shed-roof paper-covered houses was found to add greatly in reducing the temperature during spring and summer. In experiments at the Connecticut Storrs station, Jones and Card (*37*) demonstrated the effectiveness of a curtain of unbleached muslin in allowing fresh air to pass in and moist foul air to pass out of a poultry house without submitting the chickens to drafts. Similar results were obtained by Kempster (*38*) at the Missouri station. He also found that 1 square foot of muslin should be placed on the south side of the poultry house for every 15 square feet of floor space if the house is 15 feet wide, for every 20 square feet if the house is 10 feet wide, and for every 10 square feet if the house is 20 feet wide. The height of the tops of windows on the south side should be a little less than one-half the width of the house.

Experiments at the Minnesota station (*39*) showed that the average temperatures in poultry houses were lower with muslin fronts than with glass fronts. Schoppe (*40*) found in experiments at the Montana station that the combination curtain and glass-front house was extremely satisfactory in many sections of the State. It provided better ventilation and more sunshine than the open-front house with no glass and did not expose the birds to draft. A wide house was found to be better than a narrow one, since it placed the roosts farther from the openings in the front and the birds were less affected by outside changes in temperature. It was found advisable to sheathe houses on the inside to afford extra protection during extreme weather and to sheathe them overhead to cut down the air space as much as possible.

In a two-season study at the New Jersey stations of winter and summer temperatures and humidities in six different types of poultry houses, Lewis and Thompson (*41*) showed that in order to be efficient the average poultry house should be warmer than the outside normal temperature in winter and cooler than the outside normal temperature in the summer, with the difference somewhat greater in the winter than in the summer. The use of solid glass sash in the poultry house with no adequate means of continuous ventilation was found to be conducive to frozen combs and cold. An increase in height of the poultry house also made it colder. The use of some muslin and some glass improved matters for shed-roof types, and during the winter a shed-roof frame laying house divided into four pens and having a hinged clapboard on the outside of the back wall for ventilation and a concrete floor and foundation, was the warmest and driest. A half-monitor house with entire glass front in the peak and elevated about 2 feet from the ground was exceptionally cold and damp. During the summer a shed-roof type built entirely of lumber was the coolest.

METHODS OF STUDY

Most of the studies on the ventilation of animal shelters at the stations have been conducted in service barns and houses. An estimate has usually been made of the values of the important ventilation factors corresponding to the best health and comfort of the animals, an arbitrarily chosen system of ventilation has been installed, and observations of the values of the ventilation factors made as well as possible under variable conditions of weather and the extremely variable conditions of the animals themselves, these to be used as a basis for modification of the ventilation system until satisfactory.

However, attempts have been made in certain cases to introduce at least partial control in some of these studies. For example, Armsby (*42*) attempted to control his studies of the health and comfort requirements of animals and of the corresponding ventilation factors by the use of a respiration calorimeter. By this means he was able to study heat and food values (*43*), with particular reference to the nature, amount, and rate at which heat is produced by the animal body. Armsby (*44*) finally developed a calorimeter at the Pennsylvania station adapted to livestock, from which he was able to deduce the most recent and apparently most reliable data on heat production, air purity and humidity, and natural ventilation motivation with reference to cattle, horses, sheep, and swine (*4*). Benedict and his coworkers at the New Hampshire station (*45*) have also devised an apparatus for quickly and conveniently measuring the amount of carbon dioxide eliminated by large domestic animals.

A similarly comprehensive method f procedure is being planned at the owa station in studies of poultry-ouse ventilation to determine the mounts and rates of ventilation cor-esponding to the optimum values of he ventilation factors under Iowa onditions and to design ventilation ystems accordingly.

Since controlled studies of this nature nvolve heat losses through building aterials, it is of interest to note that Cumings (*46*) has recently conducted tudies at the Colorado station on heat osses through commercial wall board, which showed that the average coeffi-ient of heat transmission varied for he different types from 0.73 to 1.01. Four types of wall board had coeffi-ients varying from 0.78 to 0.81.

CONCLUSION

It seems very generally agreed that rather fine balance must exist be-ween temperature, humidity, air urity, and amount and rate of venti-ation in livestock and poultry shelters n order to insure optimum conditions f health, comfort, and economical roduction in the animal or fowl. It s therefore important to plan and onduct ventilation studies so as to efinitely establish the proper propor-ions of these factors for different pecies of animal under different anges of climatic conditions.

To be of value for this purpose the tudies must be conducted under abso-utely controlled conditions. Enough work has been done to demonstrate the utility of attempting to standardize he important ventilation factors until ethods and apparatus are available which will introduce a control of ani-al body processes and ventilation actors equivalent to that in respira-ion calorimetric investigations.

Obviously such studies should be egun with animals already in the op-imum of condition, as judged by suit-ble standards, and an effort should e made to maintain this optimum. Observations made of ventilation fac-ors during such a procedure should ield optimum values therefor and hould provide the soundest possible asis for the design of systems to sup-ly the indicated necessary amounts nd rates of ventilation.

REFERENCES

(1) A preliminary experiment on the influence of imperfect ventilation upon milch cows. F. H. King. Wis. Sta. Rpt. 1891, pp. 61–68.

(2) Tuberculosis of animals. S. S. Buckley. Md. Sta. Bul. 145. 1910.

(3) Ventilation for dwellings, rural schools, and stables. F. H. King. Madison, Wis.: Author. 1908.

(4) Some fundamentals of stable ventilation. H. P. Armsby and M. Kriss. *In* Jour. Agr. Research [U. S.], 21 (1921), pp. 343–368.

(5) Carbon dioxid content of barn air. M. F. Hendry and A. Johnson. *In* Jour. Agr. Research [U. S.], 20 (1920), pp. 405–408.

(6) Report of Committee on Farm Building Ventilation. W. B. Clarkson et al. *In* Amer. Soc. Agr. Engin. Trans., 12 (1918) pp. 282–306.

(7) The amount of air space required in poultry houses. K. J. J. Mackenzie and E. J. Russell. *In* Jour. Southeast. Agr. Col., Wye, 1904, No. 13, pp. 84–102.

(8) Ventilation of poultry houses. K. J. J. Mackenzie and E. J. Russell. *In* Highland and Agr. Soc. Scot. Trans., 5. ser., 20 (1908), pp. 87-100.

(9) Experiment in warming a stable for cows. W. P. Brooks. Mass. Hatch Sta. Rpt. 1895, p. 205.

(10) The effect of different stable temperatures upon the milk yield of dairy cows. W. B. Richards and E. L. Jordan. Wis. Sta. Rpt. 1904, pp. 143-148.

(11) Climatic dairy barns. W. B. Clarkson and C. S. Whitnah. *In* Agr. Engin., 1 (1920), pp. 23-26.

(12) The carbon dioxid: heat ratio in cattle. H. P. Armsby, J. A. Fries, and W. W. Braman. *In* Natl. Acad. Sci. Proc., 6 (1920), pp. 263-265.

(13) Feeding experiments with chickens. T. D. Hinebauch. N. Dak. Sta. Rpt. 1896, pp. 16-18.

(14) Poultry experiments. J. H. Stewart and H. Atwood. W. Va. Sta. Bul. 60, pp. 50-63. 1899.

(15) Mont. Sta. Rpt. 1902, pp. 96-100.

(16) Comparison of warm *v.* cold houses as regards egg production. H. L. Kempster. *In* Mich. Acad. Sci. Rpt., 12 (1910), pp. 85, 86.

(17) Poultry house construction and its influence on the domestic fowl. C. L. Opperman. Md. Sta. Bul. 146. 1910.

(18) Description of the new dairy and stock-judging building. W. L. Carlyle. *In* Wis. Sta. Rpt. 1898, pp. 269–282.

(19) The King system of stable ventilation. W. H. Jordon. N. Y. State Sta. Circ. 7, n. ser. 1906. Reprinted in N. Y. State Sta. Rpt. 1906, p. 106.

(20) Reconstruction of dairy barns. Bul. [Me.] Dept. Agr., 7 (1908), pp. 41–63.

(21) The King system of ventilation. C. A. Ocock. Wis. Sta. Bul. 164. 1908.

(22) Dairy barns. O. R. Zeasman, G. C. Humphrey, and L. M. Schindler. Wis. Sta. Bul. 325. 1921.

(23) Ventilation of farm stables. J. B. Reynolds. Ontario Agr. Col. Expt. Farm Rpt. 1901, pp. 11–15.

(24) Stable ventilation. J. H. Grisdale. Canada Expt. Farms Rpts. 1907, pp. 48–56.

(25) Muslin curtain ventilation *v.* Massey system and King system. W. H. Day. Ontario Agr. Col. and Expt. Farm Ann. Rpt. 1908, pp. 58–64.

(26) Ventilation of farm buildings. J. H. Grisdale and E. S. Archibald. Canada Expt. Farms Bul. 78. 1914.

(27) A comparison of the King and Rutherford systems of barn ventilation. L. J. Smith. *In* Amer. Soc. Agr. Engin. Trans., 8 (1914), pp. 42–54.

(28) Barn ventilation. L. J. Smith. Manitoba Agr. Col. Bul. 33. 1918.

(29) Barn ventilation test at Brandon Experiment Station [Manitoba]. L. J. Smith. *In* Agr. Engin., 1 (1920), pp. 79–81.

(30) The importance of heat in the correct ventilation of hog houses. W. B. Clarkson and C. S. Whitnah. *In* Agr. Engin., 1 (1920), pp. 68–70.

(31) Temperature not affected by ventilation. R. L. Patty. *In* Swine World, vol. 8, No. 16, pp. 9, 39. 1921.

(32) Test of a fan system of ventilation for dairy barns. M. A. R. Kelley. *In* Agr. Engin., 2 (1921), pp. 203–206.

(33) The design of outtake flues for stable ventilation. J. L. Strahan. *In* Agr. Engin., 2 (1921), pp. 207–209.

(34) Factors influencing the design and operation of farm building ventilation systems. M. A. R. Kelley. *In* Agr. Engin., 3 (1922), pp. 150–154.

(35) Test of a hog-house ventilation system. M. A. R. Kelley. *In* Agr. Engin., 3 (1922), pp. 164–167.

(36) Studies in poultry house construction. H. R. Lewis and A. L. Clark. N. J. Stas. Rpt. 1912, pp. 104–124.

(37) Poultry house construction. R. E. Jones and L. E. Card. Conn. Storrs Sta. Bul. 81, pp. 31–55. 1915.

(38) The farmer's poultry house. H. L. Kempster. Mo. Sta. Circ. 75. 1915.

(39) Poultry management. Minn. Sta. Rpt. 1916, pp. 78, 79.

(40) Poultry houses. W. F. Schoppe. Mont. Sta. Circ. 72. 1917.

(41) Poultry buildings: Laying and breeding houses. H. R. Lewis and W. C. Thompson. N. J. Stas. Bul. 325. 1917.

(42) The respiration calorimeter at the Pennsylvania Station. H. P. Armsby. *In* Expt. Sta. Rec., 15 (1903–04), pp. 1037–1050.

(43) Heat values and food values. H. P. Armsby. *In* Arch Ped., 22 (1905). Feb., pp. 124–130.

(44) The respiration calorimeter at the Institute of Animal Nutrition of the Pennsylvania State College. H. P. Armsby. Pa. Sta. Bul. 104. 1910.

(45) A respiration chamber for large domestic animals. F. G. Benedict, W. E. Collins, M. F. Hendry, and A. Johnson. N. H. Sta. Tech. Bul. 16, 1920.

(46) Heat transmission of commercial wall board. G. A. Cumings. Colo. Sta. Bul. 282. 1923.

INSULAR EXPERIMENT STATIONS

The agricultural experiment stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands of the United States were maintained as in previous years, through appropriations made directly to the United States Department of Agriculture as follows: Alaska, $75,000; Hawaii, $50,000; Porto Rico, $50,000; Guam, $15,000; and Virgin Islands, $20,000. These appropriations were the same as they have been since 1920, except that that for Guam was reduced $10,000. The provisions of the Hatch and Adams Acts do not apply to these stations.

The work and expenditures of the stations were supervised as heretofore by the Office of Experiment Stations through Walter H. Evans, Chief of Insular Stations. Statistics relating to the stations are reported on pages 114–117. The results of their work are reported in separate publications.

Few changes were made in the personnel or projects of the stations during the year. All of the projects, however, were reviewed and some were suspended or terminated in an effort to concentrate on the more pressing problems. Most of the projects are planned to bring about a diversified agriculture. Fundamental problems are by no means neglected, but considerable work must of necessity be done in adapting the results of experimentation in other regions to the conditions found in Alaska and the Tropics.

The Smith-Lever Extension Act has not yet been extended to these stations. They have therefore been compelled to do some extension work. In Alaska surveys were made during the summer of 1922 of some of the principal valleys to learn their problems and to furnish a basis for advising settlers as to the practices best adapted to the local conditions. In Hawaii a special effort has been made to reach the younger people, and many boys' and girls' clubs have been formed on the principal islands. This work has been taken up enthusiastically and is meeting with much success. In Porto Rico the Insular Government has recently taken over most of the extension work and the station now acts merely in an advisory and educational capacity. In Guam and the Virgin Islands the stations are doing as much extension work as their limited funds and personnel will permit without detriment to other important work of the stations. In both of these regions there is need for more work of this character, as the people are not able unaided to put into practice the results of the station experiments.

All of the stations are in need of additional funds to develop their work and utilize their equipment to the best advantage, and to extend the practical use of the experimental results.

PUBLICATIONS OF THE EXPERIMENT STATIONS DURING THE FISCAL YEAR 1923

BACTERIOLOGY—BOTANY—CHEMISTRY

Methods of determining the number of microorganisms in tomato products. C. A. Darling. (N. Y. State Sta. Tech. Bul. 91, pp. 56. Nov., 1922.)

Distribution of Arizona wild cotton (*Thurberia thespesioides*). H. C. Hanson (Ariz. Sta. Tech. Bul. 3, pp. 48–59, figs. 3. Apr., 1923.)

Violets of North America. E. Brainerd. (Vt. Sta. Bul. 224, pp. 172, pls. 25, figs. 66. Dec., 1921.)

The determination of biologic forms of *Puccinia graminis* on *Triticum* spp. E. C. Stakman and M. N. Levine. (Minn. Sta. Tech. Bul. 8, pp. 10, fig. 1. July, 1922.)

The effect of hydrogen ion concentration upon the growth of seedlings. L. W. Tarr and S. C. Noble. (Del. Sta. Bul. 131, pp. 52, figs. 11. June, 1922.)

The nature and reaction of water from hydathodes. J. K. Wilson. (N. Y. Cornell Sta. Mem. 65, pp. 11. Feb., 1923.)

Studies with corn pollen.—I, Analysis and composition of corn pollen.—II, Concerning certain lipoids, a hydrocarbon, and phytosterol occurring in the pollen of white flint corn. R. J. Anderson and W. L. Kulp. (N. Y. State Sta. Tech. Bul. 92, pp. 37. Feb., 1923.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. (Mass. Sta. Met. Buls. 402–413, pp. 4 each. June, 1922–May, 1923.)

Ohio weather for 1921. W. H. Alexander and C. A. Patton. (Ohio Sta. Bul. 360, pp. 217–312, figs. 62. June, 1922.)

SOILS

The reaction of soils in the field as influenced by the long-continued use of fertilizer chemicals. P. S. Burgess. (R. I. Sta. Bul. 189, pp. 35. Apr., 1922.)

Studies on active bases and excess acids in mineral soils. C. H. Spurway. (Mich. Sta. Tech. Bul. 57, pp. 27, figs. 11. Oct., 1922.)

A study of the influence of the lime-magnesia ratio on soils under continuous cultivation. H. H. Hill. (Va. Sta. Tech. Bul. 24, pp. 15, fig. 1. Mar., 1922.)

The effect of lime and organic matter on the so-called hardpan subsoils. M. A. Beeson and H. F. Murphy. (Okla. Sta. Bul. 143, pp. 7. Mar., 1922.)

The formation of sodium carbonate in soils. A. B. Cummins and W. P. Kelley. (Calif. Sta. Tech. Paper 3, pp. 35. Mar., 1923.)

The removal of sodium carbonate from soils. W. P. Kelley and E. E. Thomas. (Calif. Sta. Tech. Paper 1, pp. 24. Jan., 1923.)

The fixation of phosphoric acid by the soil. G. S. Fraps. (Tex. Sta. Bul. 304, pp. 22. Dec., 1922.)

The influence of precipitation on soil composition and on soil organic matter maintenance. F. J. Sievers and H. F. Holtz. (Wash. Col. Sta. Bul. 176, pp. 32, fig. 1. Feb., 1923.)

Organic constituents of the soil. G. S. Fraps. (Tex. Sta. Bul. 300, pp. 14. Sept., 1922.)

Some relations of organic matter in soils. F. A. Carlson. (N. Y. Cornell Sta. Mem. 61, pp. 27, figs. 2. Sept., 1922.)

The color of soils in relation to organic matter content. P. E. Brown. (Iowa Sta. Research Bul. 75, pp. 275–300, figs. 14. Mar., 1923.)

Fixation of nitrogen in Colorado soils.—Occurrence of nitrates on rocks. W. P. Headden. (Colo. Sta. Bul. 277, pp. 48. May, 1922.)

Water-holding capacity of irrigated soils. O. W. Israelson and F. L. West. (Utah Sta. Bul. 183, pp. 24, figs. 7, Nov., 1922.)

De Kalb County soils. J. G. Mosier, H. W. Stewart, E. E. De Turk, H. J. Snider, and L. H. Smith. (Ill. Sta. Soil Rpt. 23, pp. 54, pls. 2, figs. 7. June, 1922.)

Adams County soils. J. G. Mosier, F. W. Wascher, W. R. Leighty, H. J. Snider, and L. H. Smith. (Ill. Sta. Soil Rpt. 24, pp. 62, pls. 4, figs. 9. Aug., 1922.)

The Iowa soil survey and field experiments. W. H. Stevenson and P. E. Brown, (Iowa Sta. Circ. 82, pp. 23, figs. 8. Mar., 1923.)

Soil survey of Iowa—Palo Alto County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 22, pp. 62, pl. 1, figs. 10. June, 1922.)

Soil survey of Iowa—Winnebago County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 23, pp. 60, pl. 1, figs. 11. June, 1922.)

Soil survey of Iowa—Polk County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 24, pp. 72, pl. 1, figs. 11. June, 1922.)

Soils of Bell, Jefferson, Smith, Taylor, and Webb Counties. G. S. Fraps. (Tex. Sta. Bul. 301, pp. 66, figs. 7, Sept., 1922.)

The needs of the soils of Brazos and Jefferson Counties for sulphur. S. Lomanitz. (Tex. Sta. Bul. 302, pp. 23, figs. 2. Sept., 1922.)

Farming the silt loams of central Wisconsin. F. L. Musbach. (Wis. Sta. Bul. 347, pp. 36, figs. 17. Oct. 1922.)

Agriculture in cut-over redwood lands. W. T. Clarke. (Calif. Sta. Bul. 350, pp. 165–186, figs. 9. Oct., 1922.)

How Greece can produce more food. C. G. Hopkins. (Ill. Sta. Bul. 239, pp. 429–467, figs. 16. July, 1922.)

FERTILIZERS

Results of fertilizer experiments. M. Nelson and W. H. Sachs. (Ark. Sta. Bul. 180, pp. 23. May, 1922.)

A thirty-year fertilizer test. S. B. Haskell. (Mass. Sta. Bul. 212, pp. 127–158, pls. 2, figs. 3. Nov., 1922.)

Forty years results with fertilizers.—General fertilizer experiments. F. D. Gardner, C. F. Noll, and R. D. Lewis. (Pa. Sta. Bul. 175, pp. 23, figs. 10. Jan., 1923.)

Standard fertilizers for Michigan. M. M. McCool, G. M. Grantham, and P. M. Harmer. (Mich. Sta. Circ. 53, pp. 4. Jan., 1923.)

Nitrogenous fertilizer experiments. C. B. Walker, E. C. Ewing, and I. P. Trotter. (Miss. Sta. Bul. 207, pp. 24, figs. 2. Apr., 1922.)

The production and utilization of manure on Illinois dairy farms. H. A. Ross. (Ill. Sta. Bul. 240, pp. 473–489, figs. 3. July, 1922.)
Fermentation and preservation of manure. R. C. Collison and H. J. Conn. (N. Y. State Sta. Bul. 494, pp. 74, pls. 6, fig. 1. May, 1922.)
Acid phosphate, a good manure preservative. J. D. Luckett. (N. Y. State Sta. Bul. 494, pop. ed., pp. 7, fig. 1. July, 1922.)
Leguminous plants as organic fertilizers in California agriculture. P. B. Kennedy. (Calif. Sta. Circ. 255, pp. 8, fig. 1. Dec., 1922.)
Lime for Van Buran County soils. M. M. McCool, J. O. Veatch, and F. W. Trull. (Mich. Sta. Circ. 54, pp. 4, fig. 1. Jan., 1923.)
Lime for St. Joseph County soils. M. M. McCool and L. C. Wheeting. (Mich. Sta. Circ. 55, pp. 4, fig. 1. Apr., 1923.)
Lime for Cass County soils. M. M. McCool and J. O. Veatch. (Mich. Sta. Circ. 56, pp. 4, fig. 1. Apr., 1923.)
Lime for Calhoun County soils. M. M. McCool and J. O. Veatch. (Mich. Sta. Circ. 57, pp. 4, fig. 1. Apr., 1923.)
Lime for Berrien County soils. M. M. McCool and J. O. Veatch. (Mich. Sta. Circ. 58, pp. 4, fig. 1. Apr., 1923.)
Lime for Ottawa County soils. M. M. McCool and J. O. Veatch. (Mich. Sta. Circ. 59, pp. 4, fig. 1. Apr., 1923.)
Lime for Kalamazoo County soils. M. M. McCool, J. O. Veatch, and J. Tyson. (Mich. Sta. Circ. 60, pp. 4, fig. 1. Apr., 1923.)

FIELD CROPS

CORN

Corn experiments, 1922. J. F. O'Kelly and R. Cowart. (Miss. Sta. Circ. 47, pp. 7. Jan., 1923.)
Corn investigations. T. A. Kiesselbach. (Nebr. Sta. Research Bul. 20, pp. 151, figs. 36. June, 1922.)
Productive seed corn. T. A. Kiesselbach. (Nebr. Sta. Bul. 188, pp. 35, figs. 7. Apr., 1923.)
The linkage of certain aleurone and endosperm factors in maize, and their relation to other linkage groups. C. B. Hutchison. (N. Y. Cornell Sta. Mem. 60, pp. 1421–1473, figs. 3. June, 1922.)
Scarred endosperm and size inheritance in kernels of maize. W. H. Eyster. (Mo. Sta. Research Bul. 52, pp. 10, pls. 2, figs. 2. July, 1922.)
Varieties of corn and their adaptability to different soils. C. A. Mooers. (Tenn. Sta. Bul. 126, pp. 39, figs. 15. Mar., 1922.)
Corn varieties for chinch-bug infested areas. W. P. Flint and J. C. Hackleman. (Ill. Sta. Bul. 243, pp. 539–550, figs. 6. Apr., 1923.)
Corn culture. G. R. Quesenberry. (N. Mex. Sta. Bul. 132, pp. 43, figs. 11. Apr., 1922.)

COTTON

Cotton experiments, 1921, Delta Branch Station. W. E. Ayres. (Miss. Sta. Circ. 42, pp. 8, figs. 2. Dec., 1921.
Cotton experiments, 1922, Delta Branch Station. W. E. Ayres. (Miss. Sta. Bul. 215, pp. 14, fig. 1. Jan., 1923.)
Cotton experiments, 1922, central station. J. F. O'Kelly and R. Cowart. (Miss. Sta. Circ. 45, pp. 7. Dec., 1922.)
Cotton experiments, 1922, South Mississippi Branch Station. E. B. Ferris. (Miss. Sta. Circ. 46, pp. 6, Jan., 1923.)
Experiments with cotton and peanuts and crops grown in rotation with them in Nansemond County. E. T. Batten. (Va. Sta. Bul. 229, pp. 22, figs. 6. Oct., 1922.)
Results of cotton variety tests. (Ala. Sta. Circ. 47, pp. 10, fig. 1. Feb., 1923.)
Cotton variety tests, with suggestions for growing cotton under boll weevil conditions. G. Briggs. (Okla. Sta. Bul. 141, pp. 15. Jan., 1923.)
Varieties of cotton in northwest Texas. R. E. Karper. (Tex. Sta. Bul. 299, pp. 26, figs. 3. Aug., 1922.)
Fertilizer experiments with cotton. J. T. Williamson and M. J. Funchess. (Ala. Sta. Bul. 219, pp. 24, figs. 2. Mar., 1923.)
Fertilizer experiments with cotton. C. P. Blackwell. (S. C. Sta. Bul 211, pp. 22, fig. 1. June, 1922.)
Cotton spacing. H. B. Brown. (Miss. Sta. Bul. 212, pp. 16. Jan., 1923.)

FLAX

Flax in Montana, 1923. (Mont. Sta. Circ. 113, pp. 8, figs. 10. May, 1923.)
Wheat and flax as combination crops. A. C. Arny. (Minn. Sta. Bul. 204, pp. 21, figs. 4. Mar., 1923.)

FORAGE CROPS AND PASTURES

Experiments with alfalfa and grasses at the Judith Basin Substation. N. F. Woodward. (Mont. Sta. Bul. 152, pp. 24, figs. 7. Jan., 1923.)
Annual forage crops on dry land at the Judith Basin Substation. N. F. Woodward. (Mont. Sta. Bul. 153, pp. 15, figs. 4. Jan., 1923.)
West Virginia pastures. I. S. Cook. (W. Va. Sta. Bul. 177, pp. 23, figs. 4. July, 1922.)
Inoculation in the growing of legumes. P. W. Allen. (Wash. Col. Sta. Pop. Bul. 122, pp. 16, figs. 6. Jan., 1923.)
Leguminous crops for Guam. G. Briggs. (Guam Sta. Bul. 4, pp. 29, pls. 14. Nov., 1922.)
Alfalfa in the Delta. G. B. Walker. (Miss. Sta. Bul. 209, pp. 14, figs. 5. Feb. 1922.)
The value of lime and inoculation for alfalfa and clover on acid soils. E. J. Graul and E. B. Fred. (Wis. Sta. Research Bul. 54, pp. 22, figs. 4. Oct., 1922.)
Make alfalfa a sure crop. R. A. Moore and L. F. Graber. (Wis. Sta. Bul. 349, pp. 24, pls. 2, figs. 23. Dec., 1922.)
Field peas. G. R. Hyslop. (Oreg. Sta. Circ. 34, pp. 2. Mar., 1923.)
The small-seeded horse bean. P. B. Kennedy. (Calif. Sta. Circ. 257, pp. 23, pl. 1, figs. 14. Feb., 1923.)
Self-fertility in red clover. E. N. Fergus. (Ky. Sta. Circ. 29, pp. 19–36. Dec. 1922.)
The sorghums in Guam. G. Briggs. (Guam Sta. Bul. 3, pp. 28, pls. 9. Aug., 1922.)
Soybeans. H. D. Hughes and F. S. Wilkins. (Iowa Sta. Circ. 84, pp. 15, figs. 7. Mar., 1923.)
Sweet clover for summer pasture and green manure. J. E. Metzger. (Md. Sta. Bul. 253, pp. 37–46, figs. 2. Mar., 1923.)
Hairy vetch. C. R. Megee. (Mich. Sta. Circ. 50, pp. 8, figs. 4. July, 1922.)
Hungarian vetch in Oregon. H. A. Schoth (Oreg. Sta. Circ. 46, pp. 4. June, 1923.)
Silage experiments. T. B. Hutcheson and T. K. Wolfe. (Va. Sta. Bul. 227, pp. 16 fig. 1. Mar., 1922.)
Filling silos. J. B. Fitch. (Kans. Sta Circ. 95, pp. 8, figs. 3. Aug., 1922.)
Oats and vetch versus corn or sunflowers for silage. R. C. Jones. (Oreg. Sta Bul. 194, pp. 20, figs. 2. Dec., 1922.)

POTATOES AND SWEET POTATOES

Degeneration in Colorado potatoes. E. P. Sandsten and C. M. Tompkins. (Colo. Stat. Bul. 278, pp. 15, figs. 8. Nov., 1922.)
Fertilizer, variety, and seed selection experiments on Irish and sweet potatoes. T. H. White. (Md. Sta. Bul. 251, pp. 23. Jan., 1923.)
Potato culture in Michigan. H. C. Moore. (Mich. Sta. Spec. Bul. 117, pp. 32, figs. 20. Oct., 1922.)
Spraying Irish potatoes. J. T. Rosa, jr. (Mo. Sta. Bul. 198, pp. 8, figs. 2. Jan., 1923.)
Varieties of potatoes for Nebraska. H. O. Werner. (Nebr. Sta. Bul. 182, pp. 39, figs. 18. Nov., 1922.)
A study, by the crop survey method, of factors influencing the yield of potatoes. E. V. Hardenburg. (N. Y. Cornell Sta. Mem. 57, pp. 1143–1279, figs. 11. June, 1922.)
Better seed potatoes for Oklahoma. W. A. Radspinner. (Okla. Sta. Circ. 54, pp. 7. Jan., 1923.)
Truck crop investigations.—Storing and bedding sweet potato stock. F. W. Geise. (Va. Truck Sta. Bul. 39–40, pp. 223–234, figs. 8. July, 1922.)

WHEAT

Spring wheat production in eastern Wyoming. A. L. Nelson. (Wyo. Sta. State Farms Bul. 1, pp. 12. Dec., 1920.)
Winter wheat production in eastern Wyoming. A. L. Nelson. (Wyo. Sta. State Farms Bul. 2, pp. 15–22. Dec., 1920.)
The genetics of squareheadedness and of density in wheat and the relation of these to other characters. S. Boshnakian. (N. Y. Cornell Sta. Mem. 53, pp. 801–882, figs. 12. May, 1922.)
Kota wheat. L. R. Waldron, T. E. Stoa, and C. E. Mangels. (N. Dak. Sta. Circ. 19, pp. 10, figs. 3. Dec., 1922.)
Wheat, continuous, with and without manure. M. A. Beeson. (Okla. Sta. Bul. 140, pp. 15, figs. 4. Apr., 1921.)
Wheat growing after fallow in eastern Oregon. D. E. Stephens and G. R. Hyslop. (Oreg. Sta. Bul. 190, pp. 35, figs. 13. May, 1922.)
The effect of available nitrogen on the protein content and yield of wheat. R. E. Neidig and R. S. Snyder. (Idaho Sta. Research Bul. 1, pp. 56, pls. 7. Feb., 1922.)
Milling and baking studies with wheat.—Report of progress. W. O. Whitcomb, W. F. Day, and M. J. Blish. (Mont. Sta. Bul. 147, pp. 23, figs. 7. Dec., 1921.)

OTHER CEREALS

The feeding power of certain cereals, and their response to fertilizer ingredients. B. L. Hartwell and F. R. Pember. (R. I. Sta. Bul. 190, pp. 27, figs. 2. Nov., 1922.)
The irrigation of barley. F. S. Harris and D. W. Pittman. (Utah Sta. Bul. 178, pp. 19, figs. 10. Oct., 1922.)
Inheritance and yield with particular reference to rust resistance and panicle type in oats. R. J. Garber. (Minn Sta. Tech. Bul. 7, pp. 62, pls. 6. July, 1922.)
Varietal trials with oats in North Dakota. T. E. Stoa. (N. Dak. Sta. Bul. 164, pp. 47, figs. 7. July, 1922.)
Oats: Rotation vs. continuous culture. H. F. Murphy. (Okla. Sta. Bul. 145, pp. 8, figs. 2. Mar., 1922.)
Results of rice experiments in 1922. C. F. Dunshee. (Calif. Sta. Bul. 354, pp. 399–415, figs. 14. Feb., 1923.

MISCELLANEOUS

Peanuts. E. B. Ferris. (Miss Sta. Bul. 208, pp. 14. Mar., 1922.)
Experiments with dark tobacco and other crops. B. G. Anderson. (Va. Sta. Bul. 231, pp. 19, figs. 5. Feb., 1923.)
Growing irrigated crops in Harney Valley. O. Shattuck and D. W. Ritchie. (Oreg. Sta. Bul. 191, pp. 24, figs. 15. July, 1922.)
Relation of crop yields to quantity of irrigation water in southwestern Kansas. G. S. Knapp. (Kans. Sta. Bul. 228, pp. 29, figs. 11. June, 1922.)
Recent crop yields from soil experiment field in Illinois. H. J. Snider. (Ill. Sta. Circ. 260, pp. 8. June, 1922.)
Crop rotation under irrigation. J. A. Holden. (Nebr. Sta. Bul. 190, pp. 11. Apr., 1923.)
Crop rotation and soil fertility. W. L. Powers and C. V. Ruzek. (Oreg. Sta. Circ. 44, pp. 12, fig. 1. June, 1923.)

WEEDS

The control of wild morning glory. C. C. Barnum. (Calif. Sta. Circ. 256, pp. 22, figs. 13. Jan., 1923.)
Russian knapweed, a new weed in Kansas. R. L. Hensel and Mrs. E. P. Harling, (Kans. Sta. Circ. 94, pp. 4, figs. 2. July, 1922.)
Observations on some rice weeds in California. P. B. Kennedy. (Calif. Sta. Bul. 356, pp. 465–494, figs. 26. Apr., 1923.)
North Dakota weeds. O. A. Stevens. (N. Dak. Sta. Bul. 162, pp. 44, figs. 45. June, 1922.)

HORTICULTURE AND FORESTRY

ORCHARD FRUITS

Orchard survey of the southwestern district of Colorado. E. P. Sandsten and C. M. Tompkins. (Colo. Sta. Bul. 274, pp. 21. June, 1922.)
Orchard survey of the western district of Colorado. E. P. Sandsten and C. M. Tompkins. (Colo. Sta. Bul. 275, pp. 45. June, 1922.)
New or noteworthy fruits, VI. U. P. Hedrick. (N. Y. State Sta. Bul. 497, pp. 19, pls. 8. Jan., 1923.)
Experiments in soil management and fertilization of orchards. J. K. Shaw. (Mass. Sta. Bul. 209, pp. 33–60, figs. 11. July, 1922.)
Final report on the cooperative experiments in orchard fertilization. R. C. Collison and J. D. Harlan. (N. Y. State Sta. Bul. 503, pp. 30. Apr., 1923.)
Pruning fruit trees. R. E. Marshall. (Mich. Sta. Spec. Bul. 118, pp. 39, figs. 39. Oct., 1922.)
Results of some experiments in pruning fruit trees. W. H. Chandler. (N. Y. Cornell Sta. Bul. 415, pp. 75, figs. 15. Jan., 1923.)
The modified leader tree. R. H. Roberts. (Wis. Sta. Bul. 354, pp. 32. Feb., 1923.)
Thinning deciduous fruits. W. P. Tufts. (Calif. Sta. Circ. 258, pp. 13, figs. 5. Mar., 1923.)
Effect of defoliation upon blossom bud formation. R. H. Roberts. (Wis. Sta. Research Bul. 56, pp. 15, figs. 5. Jan., 1923.)
The relation of temperature to blossoming in the apple and the peach. F. C. Bradford. (Mo. Sta. Research Bul. 53, pp. 51, figs. 9. Aug., 1922.)

The development and winter injury of cherry blossom buds. R. H. Roberts. (Wis. Sta. Research Bul. 52, pp. 24, pls. 4, figs. 7. July, 1922.)
Effect of climatic conditions on the blooming and ripening dates of fruit trees. H. A. Phillips. (N. Y. Cornell Sta. Mem. 59, pp. 1379–1416, figs. 9. June, 1922.)
Observations on winter injury. F. C. Bradford and H. A. Cardinell. (Mo. Sta. Research Bul. 56, pp. 26, figs. 27. Nov., 1922.)
Winter injury of fruit in Missouri. F. C. Bradford. (Mo. Sta. Circ. 107, pp. 7. Sept., 1922.)
Preliminary smudging experiments. F. Garcia and A. B. Fite. (N. Mex. Sta. Bul. 134, pp. 26, figs. 6. Dec., 1922.)
The relation of tree type to productivity in the apple. K. Sax and J. W. Gowen. (Me. Sta. Bul. 305, pp. 20, pls. 4, figs. 3. Mar., 1922.)
Sterility relationships in Maine apple varieties. K. Sax. (Me. Sta. Bul. 307, pp. 61–76, fig. 1. Sept., 1922.)
Factors influencing catalase activity in apple-leaf tissue. A. J. Heinicke. (N. Y. Cornell Sta. Mem. 62, pp. 19. Jan., 1923.)
Leaf characters of apple varieties. J. K. Shaw. (Mass. Sta. Bul. 208, pp. 20–31, pls. 12, fig. 1. Apr., 1922.)
The relation of soil moisture and nitrates to the effects of sod on apple trees. T. L. Lyon, A. J. Heinicke, and B. D. Wilson. (N. Y. Cornell Sta. Mem. 63, pp. 28; figs. 3. Jan., 1923.)
Methods of interpreting yield records in apple fertilization experiments. R. D. Anthony and J. H. Waring. (Pa. Sta. Bul. 173, pp. 42, figs. 3. May, 1922.)
Growth and yield of apple trees pruned in various ways. G. H. Howe. (N. Y. State Sta. Bul. 500, pp. 22, pls. 6. Mar., 1923.)
Pollination of the sweet cherry. C. E. Schuster. (Oreg. Sta. Circ. 27, pp. 3. Sept., 1922.)
Better cherry yields. R. H. Roberts. (Wis. Sta. Bul. 344, pp. 30, figs. 20. June, 1922.)
Fertilizer experiments with citrus trees. R. S. Vaile. (Calif. Sta. Bul. 345, pp. 465–512, figs. 13. June, 1922.)
Effect of sodium chlorid and calcium chlorid upon growth and composition of young orange trees. H. S. Reed and A. R. C. Haas. (Calif. Sta. Tech. Paper 4, pp. 32, pls. 6. Apr., 1923.)
Studies on the irrigation of citrus groves. E. E. Thomas. (Calif. Sta. Bul. 341, pp. 353–370. Mar., 1922.)
Pruning young olive trees. F. T. Bioletti. (Calif. Sta. Bul. 348, pp. 87–110, figs. 8. Sept., 1922.)
The pears of New York. U. P. Hedrick et al. (Rpt. N. Y. Agr. Expt. Sta. 1921, Pt. II, pp. XI + 636, pls. 82.)
The pear in New York. H. B. Tukey. (N. Y. State Sta. Bul. 495, pp. 19, fig. 1. Dec., 1922.)
Cold storage as an aid to the marketing of plums. E. L. Overholser. (Calif. Sta. Bul. 344, pp. 427–463, figs. 9. June, 1922.)
Further experiments in plum pollination. A. H. Hendrickson. (Calif. Sta. Bul. 352, pp. 245–266, figs. 5. Dec., 1922.)
Stocks for plums. U. P. Hedrick. (N. Y. State Sta. Bul. 498, pp. 19, pls. 6. Jan., 1923.)
Plum stocks. J. D. Luckett. (N. Y. State Sta. Bul. 498, pop. ed., pp. 4, pl. 1. Mar., 1923.)

GRAPES

Vineyard plans. F. T. Bioletti. (Calif. Sta. Circ. 253, pp. 12, figs. 4. Oct., 1922.)
Supports for vines. F. T. Bioletti. (Calif. Sta. Circ. 252, pp. 19, figs. 15. Sept., 1922.)
Some common errors in vine pruning and their remedies. F. T. Bioletti. (Calif. Sta. Circ. 248, pp. 8, figs. 6. June, 1922.)
Influence of grape training on fruit production. E. C. Auchter and W. R. Ballard. (Md. Sta. Bul. 250, pp. 207–234, figs. 22. June, 1922.)
Grape production in Michigan. N. L. Partridge. (Mich. Sta. Spec. Bul. 121, pp. 23, figs. 11. Feb., 1923.)
Grape growing in Oregon. C. E. Schuster. (Oreg. Sta. Circ. 43, pp. 16, figs. 5. June, 1923.)

SMALL FRUIT

Cranberry growing in New Jersey. C. S. Beckwith. (N. J. Stas. Circ. 144, pp. 39, figs. 28. Dec., 1922.)
Running-out of raspberries. W. H. Rankin. (N. Y. State Sta. Circ. 67, pp. 12. Apr., 1923.)
Some new hybrid strawberries. R. F. Howard and C. C. Wiggans. (Nebr. Sta. Bul. 189, pp. 15, figs. 2. Apr., 1923.)
Strawberries. C. E. Schuster. (Oreg. Sta. Circ. 32, pp. 16, figs. 2. Jan., 1923.)

FRUIT PRODUCTS

Fruit beverage investigations. W. V. Cruess and J. H. Irish. (Calif. Sta. Bul. 359, pp. 525–568, figs. 15. Apr., 1923.)
Fruit jellies.—I. The rôle of acids. L. W. Tarr. (Del. Sta. Bul. 134, pp. 38, figs. 10. Feb., 1923.)
Recirculation driers. E. H. Wiegand. (Oreg. Sta. Circ. 40, pp. 11, figs. 6. Apr., 1923.)
Pear by-products. J. H. Irish. (Calif. Sta. Circ. 259, pp. 4. Apr., 1923.)

SPRAYING AND DUSTING

A self-mixing dusting machine for applying dry insecticides and fungicides. R. E. Smith and J. P. Martin. (Calif. Sta. Bul. 357, pp. 497–505, figs. 3. Apr., 1923.)
Results of dusting versus spraying in Connecticut apple and peach orchards in 1922. M. P. Zappe and E. M. Stoddard. (Conn. State Sta. Bul. 245, pp. 229–243. Feb., 1923.)
Directions for spraying fruits in Illinois. (Ill. Sta. Circ. 266, pp. 16, figs. 2. Apr., 1923.)
Injury to foliage by arsenical sprays.—I, The lead arsenates. H. T. Fernald and A. I. Bourne. (Mass. Sta. Bul. 207, pp. 19, figs. 23. Apr., 1922.)
Injury to foliage by arsenical sprays. H. T. Fernald and A. I. Bourne. (Mass. Sta. Bul. 210, pp. 89–98, figs. 14. Aug., 1922.)
Bordeaux mixture.—II. Stimulatory action. O. Butler. (N. H. Sta. Tech. Bul. 21, pp. 50. June, 1922.)
Dry-mix sulfur lime.—A substitute for self-boiled lime sulfur and summer-strength concentrated lime-sulfur. A. J. Farley. (N. J. Stas. Bul. 379, pp. 16, figs. 3. Feb., 1923.)

Spraying and dusting experiments with apples in 1922. P. J. Parrott, F. C. Stewart, and H. Glasgow. (N. Y. State Sta. Circ. 63, pp. 8. [1922.])

Spray calendar. W. R. Britton and G. P. Clinton. (Conn. State Sta. Bul. 244, pp. 183–226, figs. 94. Jan., 1923.)

Spray calendar for apples and quinces. (N. J. Stas. Circ. 147, pp. 4, fig. 1. Feb., 1923.)

Spray calendar for peaches. (N. J. Stas. Circ. 148, pp. 4, figs. 3. Feb., 1923.)

Spray calendar for pears. (N. J. Stas. Circ. 149, pp. 4, figs. 3. Feb., 1923.)

Spray calendars for plums and cherries. (N. J. Stas. Circ. 150, pp. 4, fig. 1. Feb., 1923.)

Circ. 151, pp. 3, fig. 1. Feb., 1923.)

Spray calendar for grapes. (N. J. Stas. Circ. 151, pp. 3, fig. 1. Feb., 1923.)

VEGETABLES

Vegetable growing in Guam. G. Briggs. (Guam Sta. Bul. 2, pp. 60, pls. 17. June, 1922.)

Vegetables and truck for home use. W. E. Ayres. (Miss. Sta. Bul. 210, pp. 16, figs. 10. Mar., 1922.)

Truck crop investigations.—Cabbage strain tests. H. H. Zimmerley. (Va. Truck Sta. Bul. 37–38, pp. 211–220. Oct., 1921–Jan., 1922.)

Truck crop investigations.—Spraying and dusting vegetable crops in 1922. F. W. Geise, H. H. Zimmerley, and H. Spencer. (Va. Truck Sta. Bul. 41, pp. 237–256, figs. 9. Oct., 1922.)

Truck crop investigations.—Experiments with inoculated sulphur. F. W. Geise. (Va. Truck Sta. Bul. 42, pp. 259–263. Jan., 1923.)

Celery culture for Utah. T. H. Abell. (Utah Sta. Circ. 47, pp. 33, figs. 5. Sept., 1922.)

Head lettuce in Colorado. R. A. McGinty. (Colo. Sta. Bul. 283, pp. 26, figs. 9. Mar., 1923.)

Lettuce varieties. A. M. Musser and W. J. Young. (S. C. Sta. Bul. 215, pp. 16, figs. 5. Oct., 1922.)

Rocky Mountain head lettuce A. F. Vass. (Wyo. Sta. Circ. 19, pp. 11, figs. 3. Feb., 1923.)

Regarding Connecticut sweet-corn seed. E. H. Jenkins. (Conn. State Sta. Bul. Immed. Inform. 16, pp. 2. Jan., 1922.)

Tomatoes for market and canning. H. A. Jones. (Md. Sta. Bul. 248, pp. 153–187, figs. 9. Feb., 1922.)

Comparison of first generation tomato crosses and their parents. R. Wellington. (Minn. Sta. Tech. Bul. 6, pp. 27, figs. 8. July, 1922.)

Experiments in spraying and dusting tomatoes. F. D. Fromme. (Va. Sta. Bul. 230, pp. 15, figs. 5. Nov., 1922.)

MISCELLANEOUS

Almond pollination. W. P. Tufts and G. L. Philp. (Calif. Sta. Bul. 346, pp. 35, figs. 15. July, 1922.)

Filberts. C. E. Schuster. (Oreg. Sta. Circ. 28, pp. 3. Sept., 1922.)

Cultivation and care of trees on Texas farms. H. Ness. (Tex. Sta. Bul. 293, pp. 76, pls. 14, figs. 19. Feb., 1922.)

Second growth on cut-over lands in St. Louis County. T. S. Hansen. (Minn. Sta. Bul. 203, pp. 50, figs. 40. May, 1923.)

DISEASES OF PLANTS

FIELD CROP DISEASES

Diseases of grain and forage crops in North Dakota. W. Weniger. (N. Dak. Sta. Bul. 166, pp. 92, figs. 32. May, 1923.)

Potato diseases in Nebraska. R. W. Goss. (Nebr. Sta. Bul. 186, pp. 32, figs. 12. Feb., 1923.)

Relation of environment and other factors to potato wilt caused by *Fusarium oxysporum*. R. W. Goss. (Nebr. Sta. Research Bul. 23, pp. 84, figs. 5. May, 1923.)

Potato diseases in New Jersey and their control. W. H. Martin. (N. J. Sta. Circ. 146, pp. 32, figs. 25. Mar., 1923.)

The influence of soil temperature on potato scab. L. R. Jones, H. H. McKinney, and H. Fellows. (Wis. Sta. Research Bul. 53, pp. 35, pls. 4, figs. 9. July, 1922.)

Sunburn and aphid injury of soybeans and cowpeas. F. Gibson. (Ariz. Sta. Tech. Bul. 2, pp. 41–46, pls. 2, fig. 1. Sept., 1922.)

Tobacco diseases in Gadsden County in 1922 with suggestions for their prevention and control. W. B. Tisdale. (Fla. Sta. Bul. 166, pp. 73–118, figs. 15. Dec., 1922.)

Wildfire of tobacco in Connecticut. G. P. Clinton and F. A. McCormick. (Conn. State Sta. Bul. 239, pp. 363–425, pls. 4. May, 1922.)

Tobacco wildfire in 1922. P. J. Anderson and G. H. Chapman. (Mass. Sta. Bul. 213, pp. 27, fig. 1. Jan., 1923.)

Wildfire of tobacco. F. A. Wolf. (N. C. Sta. Bul. 246, pp. 26, figs. 7. Nov., 1922.)

Blackfire or angular-leafspot of tobacco. F. D. Fromme and S. A. Wingard. (Va. Sta. Tech. Bul. 25, pp. 43, pls. 2, figs. 18. Apr., 1922.)

Blackfire and wildfire of tobacco and their control. F. D. Fromme and S. A. Wingard. (Va. Sta. Bul. 228, pp. 19, pls. 2, figs. 9. Apr., 1922.)

Tobacco wildfire in Wisconsin. J. Johnson and S. B. Fracker. (Wis. Sta. Bul. 348, pp. 21, figs. 11. Dec., 1922.)

A study of the environmental conditions influencing the development of stem rust in the absence of an alternate host.—I, The viability of the urediniospores of *Puccinia graminis tritici* Form III. G. L. Peltier. (Nebr. Sta. Research Bul. 22, pp. 15, figs. 3. Sept., 1922.)

Flag smut of wheat, with special reference to varietal resistance. W. H. Tisdale, G. H. Dungan, and C. E. Leighty. (Ill. Sta. Bul. 242, pp. 509–538, figs. 3. Apr., 1923.)

Common smuts and their treatment. A. Daane. (Okla. Sta. Circ. 52, pp. 3. [1923.].)

Copper carbonate for wheat smut control. H. P. Barss. (Oreg. Sta. Circ. 30, pp. 3. Sept., 1922.)

The dusting of wheat for bunt or stinking smut. F. D. Heald and L. J. Smith. (Wash. Col. Sta. Bul. 168, pp. 15, figs. 5. June, 1922.)

The dusting of wheat for bunt or stinking smut. F. D. Heald and L. J. Smith. (Wash. Col. Sta. Bul. 171, pp. 28, figs. 5. Oct., 1922.)

FRUIT DISEASES

The brown bark spot of fruit trees. D. B. Swingle and H. E. Morris. (Mont. Sta. Bul. 146, pp. 22, figs. 6. Dec., 1921.)

Dissemination of fire blight. H. A. Gossard and R. C. Walton. (Ohio Sta. Bul. 357, pp. 79–126, figs. 16. Mar., 1922.)

Combating apple scab.—Spraying and dusting experiments in 1922. W. S. Krout. (Mass. Sta. Bul. 214, pp. 29–41. Jan., 1923.)

Avocado diseases. H. E. Stevens. (Fla. Sta. Bul. 161, pp. 23, figs. 6. May, 1922.)

Preliminary report on controlling melanose and preparing Bordeaux-oil. O. F. Burger, E. F. DeBusk, and W. R. Briggs. (Fla. Sta. Bul. 167, pp. 121–140, figs. 5. Jan., 1923.)

Black measles, water berries, and related vine troubles. F. T. Bioletti. (Calif. Sta. Bul. 358, pp. 509–524, figs. 6. Apr., 1923.)

Fruit and vegetable diseases. E. C. Stakman, J. G. Leach, and J. L. Seal. (Minn. Sta. Bul. 199, pp. 75, figs. 38. Jan., 1922.)

VEGETABLE DISEASES

Common diseases of beans and peas. M. T. Cook. (N. J. Stas. Circ. 142, pp. 8, figs. 5. Aug., 1922.)

Cabbage wilt and stem rot in Delaware. T. F. Manns. (Del. Sta. Bul. 132, pp. 24, figs. 13. June, 1922.)

A bacterial rosette disease of lettuce. R. C. Thomas. (Ohio Sta. Bul. 359, pp. 197–214, figs. 8. June, 1922.)

The diseases of pepper. B. B. Higgins. (Ga. Sta. Bul. 141, pp. 48–75, figs. 11. Feb., 1923.)

The crown rot of rhubarb caused by *Phytophthora cactorum.* W. S. Beach. (Pa. Sta. Bul. 174, pp. 28, figs. 25. July, 1922.)

Sweet potato disease in New Jersey. R. F. Poole. (N. J. Stas. Circ. 141, pp. 31, figs. 24. Sept., 1922.)

Tomato leaf spot and experiments with its control. J. H. Muncie. (Pa. Sta. Bul. 177, pp. 23, figs. 3. Dec., 1922.)

MISCELLANEOUS

The occurrence of protozoa in plants affected with mosaic and related diseases. R. Nelson. (Mich. Sta. Tech. Bul. 58, pp. 30, figs. 18. Dec., 1922.)

Alternate hosts and biologic specialization of crown rust in America. I. E. Melhus, S. M. Dietz, and F. Willey. (Iowa Sta. Research Bul. 72, pp. 211–236, figs 2. Jan., 1922.)

Experiments on the field control of snapdragon rust together with a description of a method for the control of the disease in greeenhouses. O. Butler. (N. H. Sta. Tech. Bul. 22, pp. 14, figs. 2. May, 1923.)

Control of white pine blister rust in Connecticut. W. O. Filley and H. W. Hicock. (Conn. State Sta. Bul. 237, pp. 305–326, pls. 5. Feb., 1922.)

ENTOMOLOGY AND ZOOLOGY

FIELD CROP INSECTS

Insects and other animal pests injurious to field beans in New York. I. M. Hawley. (N. Y. Cornell Sta. Mem. 55, pp. 949–1037, pls. 3, figs. 17. May, 1922.)

The clover aphis.—Biology, economic relationships, and control. R. H. Smith. (Idaho Sta. Research Bul. 3, pp. 75, figs. 35. Jan., 1923.)

The clover leaf weevil. G. W. Herrick and C. H. Hadley, jr. N. Y. Cornell Sta. Bul. 411, pp. 12, pls. 2, figs 4. July, 1922.)

Insect pests of cotton in St. Croix and means of combating them. C. E. Wilson. (Virgin Islands Sta. Bul. 3, pp. 20, figs. 21. May, 1923.)

A preliminary report upon an improved method of controlling the boll weevil. G. D. Smith. (Fla. Sta. Bul. 165, pp. 72, figs. 13. Oct., 1922.)

Boll weevil.—Life history in connection with essential methods of control. C. E. Sanborn. (Okla. Sta. Circ. 50, pp. 2. [1922.])

Suggestions relative to the boll weevil. C. E. Sanborn. (Okla. Sta. Circ. 53, pp. 16, figs. 11. [1923.])

The hop red spider. A. L. Lovett. (Oreg. Sta. Circ. 36, pp. 4, fig. 1. Apr., 1923.)

Leafhopper injury to potatoes. J. E. Kotila. (Mich. Sta. Tech. Bul. 56, pp. 27, figs. 14. July, 1922.)

Spraying for hopperburn. J. E. Kotila. (Mich. Sta. Circ. 48, pp. 4, figs. 2. July, 1922.)

The sugar cane mealy bug and its control in Louisiana. E. R. Barber. (La. Stas. Bul. 185, pp. 16, figs. 6. Jan., 1923.)

Bunch velvet means to control root-knot. J. R. Watson. (Fla. Sta. Bul. 163, pp. 53–59, figs. 2. June, 1923.)

Burn the chinch-bug. W. P. Flint. (Ill. Sta. Circ. 265, pp. 4, figs. 2. Oct., 1922.)

Fight the chinch bug with crops. W. L. Burlison and W. P. Flint. (Ill. Sta. Circ. 268, pp. 16, figs. 7. May. 1923.)

Chinch bug barriers. W. P. Flint. (Ill. Sta. Circ. 270, pp. 8, figs. 4. May, 1923.)

The chinch bug. R. H. Pettit. (Mich. Sta. Circ. 51, pp. 2, figs. 2. Aug., 1922.)

The chinch bug. H. C. Severin. (S. Dak. Sta. Bul. 202, pp. 561–576, figs. 2. Apr., 1923.)

The Hessian fly. R. H. Pettit. (Mich. Sta. Circ. 49, pp. 8, fig. 1, July, 1922.)

FRUIT INSECTS

The apple and thorn skeletonizer. B. A. Porter and P. Garman. (Conn. State Sta. Bul. 246, pp. 245–264, pls. 4, figs. 3. Feb., 1923.)

Studies on insects affecting the fruit of the apple with particular reference to the characteristics of the resulting scars. H. H. Knight. (N. Y. Cornell Sta. Bul. 410, pp. 449–498, pls. 40. May, 1922.)

The cherry-fruit fly. A. L. Lovett. (Oreg. Sta. Circ. 35, pp. 4, figs. 3. Apr., 1923.)

The citrus nematode (*Tylenchulus semi-penetrans*). E. E. Thomas. (Calif. Sta. Tech. Paper 2, pp. 34, pls. 8. May, 1923.)

The peach twig-borer (*Anarsia lineatella* Zeller). W. P. Duruz. (Calif. Sta. Bul. 355, pp. 419–464, figs. 19. Mar., 1923.)

1922 experiments on control of borers and leaf curl of peaches. P. J. Parrott, F. C. Stewart, and H. Glasgow. (N. Y. State Sta. Circ. 64, pp. 7. [1922.])

The peach and prune twig-miner. A. L. Lovett. (Oreg. Sta. Circ. 38, pp. 4, figs. 3. Apr., 1923.)

Spraying and dusting experiments for pear psylla in 1922. F. Z. Hartzell. (N. Y. State Sta. Circ. 65, pp. 8. [1922.])

The grape-berry moth in 1922. R. H. Pettit. (Mich. Sta. Circ. 52, pp. 4, figs. 4. Dec., 1922.)

The blackberry psyllid, *Trioza tripunctata* Fitch. A. Peterson. (N. J. Stas. Bul. 378, pp. 32, figs. 35. Feb., 1923.)

Insect pests and diseases of currants and gooseberries. A. L. Lovett and H. P. Barss. (Oreg. Sta. Circ. 42, pp. 12, figs. 6. June, 1923.)

The strawberry tiger moth. W. J. Baerg. (Ark. Sta. Bul. 183, pp. 14, pls. 5, figs. 4. Jan., 1923.)

Experiments on the control of the woolly aphis. E. N. Cory. (Md. Sta. Bul. 252, pp. 25–36. Feb., 1923.)

Tree borers and their control. A. L. Lovett. (Oreg. Sta. Circ. 39, pp. 7, figs. 4. Apr., 1923.)

Six years of life history studies on the codling moth. A. B. Fite. (N. Mex. Sta. Bul. 127, pp. 183, figs. 16. June, 1921.)

Summary of codling moth investigations, with spraying schedules. A. B. Fite. (N. Mex. Sta. Bul. 135, pp. 24, figs. 7. Feb., 1923.)

The fruit-tree leaf-roller in the Bitter Root Valley. W. S. Regan. (Mont. Sta. Circ. 109, pp. 13, figs. 8. Dec., 1922.)

The orchard leaf roller. A Spuler. (Wash. Col. Sta. Bul. 172, pp. 9. Nov., 1922.)

The control of red spiders in deciduous orchards. E. R. DeOng. (Calif. Sta. Bul. 347, pp. 39–83, pls. 2, figs. 10. Aug., 1922.)

Spider mites affecting orchard and garden fruits. R. H. Smith. (Idaho Sta. Circ. 25, pp. 8, figs. 3. Mar., 1922.)

Controlling San José scale with lubricating oil emulsion. L. Haseman and K. C. Sullivan. (Mo. Sta. Circ. 109, pp. 4, figs. 2. Feb., 1923.)

Tolerance of San José scale to sprays. A. L. Melander. (Wash. Col. Sta. Bul. 174, pp. 52, figs. 2. Feb., 1923.)

VEGETABLE INSECTS

The bean leaf-hopper and hopperburn with methods of control. A. H. Beyer. (Fla. Sta. Bul. 164, pp. 61–88, figs. 16. June, 1922.)

The cabbage maggot with special reference to its control. G. W. Herrick and W. Colman. (N. Y. Cornell Sta. Bul. 413, pp. 15, figs. 8. Dec., 1922.)

The onion maggot. A. L. Lovett. (Oreg. Sta. Circ. 37, pp. 4. Apr., 1923.)

The pepper maggot, a new pest of peppers and eggplants, *Spilographa electa* Say. A. Peterson. (N. J. Stas. Bul. 373, pp. 23, figs. 3. Jan., 1923.)

MISCELLANEOUS

Aphids attacking stone fruits in Idaho and methods for their control. R. H. Smith. (Idaho Sta. Circ. 26, pp. 11, figs. 9. Mar., 1922.)

Destroy the earwigs. B. B. Fulton. (Oreg. Sta. Circ. 29, pp. 3. Sept., 1922.)

Sodium arsenite as a killing agent in grasshopper baits. C. L. Corkins. (Colo. Sta. Bul. 280, pp. 15. Jan., 1923.)

Improvement in the methods of preparing and using grasshopper baits. J. R. Parker. (Mont. Sta. Bul. 148, pp. 19, fig. 1. Feb., 1922.)

Improved methods of controlling grasshoppers. R. A. Cooley, J. R. Parker, and A. L. Strand. (Mont. Sta. Circ. 112, pp. 20, fig. 1. Jan., 1923.)

Experiments with poisoned baits for grasshoppers. M. H. Swenk and E. E. Wehr. (Nebr. Sta. Bul. 183, pp. 28, fig. 1. Jan., 1923.)

Grasshoppers, cutworms, and other insect pests of 1921–22. R. A. Cooley. (Mont. Sta. Bul. 150, pp. 31, figs. 6. Dec., 1922.)

Chemotropism of mosquitoes. W. Rudolfs. (N. J. Stas. Bul. 367, pp. 23, fig. 1. Mar., 1922.)

The gloomy scale. Z. P. Metcalf. (N. C. Sta. Tech. Bul. 21, pp. 22, figs. 15. June, 1922.)

Studies in termite control. W. C. O'Kane and W. A. Osgood. (N. H. Sta. Bul. 204, pp. 20, figs. 8. Apr., 1922.)

The flower thrips. J. R. Watson. (Fla. Sta. Bul. 162, pp. 25–51, figs. 4. June, 1922.)

The white flies of hothouses. H. H. Jewett and H. Garman. (Ky. Sta. Bul. 241, pp. 77–111, figs. 10. Apr., 1922.)

The maple case-bearer. G. W. Herrick. (N. Y. Cornell Sta. Bul. 417, pp. 15, figs. 13. Apr., 1923.)

Mississippi bark beetles. M. W. Blackman. (Miss. Sta. Tech. Bul. 11, pp. 130, pls. 18, fig. 1. July, 1922.)

A contribution to our knowledge of the Syrphidae of Colorado. C. R. Jones. (Colo. Sta. Bul. 269, pp. 72, pls. 8. Apr., 1922.)

The insect fauna of the genus Crataegus. W. H. Wellhouse. (N. Y. Cornell Sta. Mem. 56, pp. 1041–1136, figs. 26. June, 1922.)

The biology of the Chrysopidae. R. C. Smith. (N. Y. Cornell Sta. Mem. 58, pp. 1287–1372, pls. 4, figs. 20. June, 1922.)

Life history of the kangaroo rat. *Dipodomys spectabilis spectabilis* Merriam. C. T. Vorhies and W. P. Taylor. (Ariz. Sta. Tech. Bul. 1, pp. 40, pls. 9, figs. 3. Sept., 1922.)

INSECTICIDES

Diffusion of carbon bisulphid in soil. W. C. O'Kane. (N. H. Sta. Tech. Bul. 20, pp. 36, figs. 21. June, 1922.)

Factors which affect the volatility of nicotine from insecticide dusts. R. W. Thatcher and L. R. Streeter. (N. Y. State Sta. Bul. 501, pp. 34. Mar., 1923.)

The aphiscidal properties of tobacco dust. G. F. MacLeod and S. W. Harman. (N. Y. State Sta. Bul. 502, pp. 18, pls. 3. Apr., 1923.)

FOODS AND HUMAN NUTRITION

Vitamins, health, and the daily diet. J. W. Read and S. Palmer. (Ark. Sta. Bul. 184, pp. 64, figs. 11. May, 1923.)

Indiana flour. (Ind. Sta. Circ. 109, pp. 15 figs. 9. Feb., 1923.)

ANIMAL PRODUCTION

FEEDING STUFFS AND ANIMAL NUTRITION

Forage crops save protein supplements. J. M. Evvard. (Iowa Sta. Circ. 83, pp. 8, figs. 2. Mar., 1923.)

Studies in animal nutrition.—II, Changes in proportions of carcass and offal on different planes of nutrition. C. R. Moulton, P. F. Trowbridge, and L. D. Haigh. (Mo. Sta. Research Bul. 54, pp. 76, pl. 1, figs. 27. Sept., 1922.)

Studies in animal nutrition.—III, Changes in chemical composition on different planes of nutrition. C. R. Moulton, P. F. Trowbridge, and L. D. Haigh. (Mo. Sta. Research Bul. 55, pp. 88, figs. 20. Oct., 1922.)

Minerals for live stock. E. B. Hart, H. Steenbock, and F. B. Morrison. (Wis. Sta. Bul. 350, pp. 21, figs. 16. Jan., 1923.)

BREEDING

Vitality of spermatozoa. W. S. Anderson. (Ky. Sta. Bul. 239, pp. 36, figs. 7. Jan., 1922.)

Sterility in relation to animal breeding. W. S. Anderson. (Ky. Sta. Bul. 244, pp. 203–234. Dec., 1922.)

Discussions and demonstrations on breeding problems. (Ky. Sta. Circ. 30, pp. 39–93. Dec., 1923.)

HORSES

Horse raising in colonial New England. D. Phillips. (N. Y. Cornell Sta. Mem. 54, pp. 889–941. Apr., 1922.)

BEEF CATTLE

Steer feeding experiments. C. W. Hickman and E. F. Rinehart. (Idaho Sta. Circ. 28, pp. 8, fig. 1. Sept., 1922.)

Cattle feeding.—Winter steer feeding. J. H. Skinner and F. G. King. (Ind. Sta. Bul. 265, pp. 23. Dec., 1922.)

Feeding steers having access to barn and range vs. steers confined to barn. E. S. Good. (Ky. Sta. Bul. 242, pp. 115–135, figs. 7. June, 1922.)

Cattle feeding investigations. W. H. Peters and N. K. Carnes. (Minn. Sta. Bul. 200, pp. 33, figs. 12. Dec., 1922.)

Experiments with feeding steers using cottonseed meal and varying proportions of corn and cottonseed meal. E. Barnett and C. J. Goodell. (Miss. Sta. Bul. 214, pp. 29. Jan., 1923.)

The utilization of feed by range steers of different ages.—III, Alfalfa hay and cottonseed meal.—IV, Alfalfa hay, milo maize meal, and cottonseed meal. J. D. Hungerford and L. Foster. (N. Mex. Sta. Bul. 128, pp. 92, figs. 15. Sept., 1921.)

The feeding of dry-farm crops to range steers in eastern New Mexico. J. L. Lantow and H. J. Clemmer. (N. Mex. Sta. Bul. 131, pp. 10, figs. 3. Mar., 1922.)

The utility of yucca and chamiza as range supplements. L. S. Brown. (N. Mex. Sta. Bul. 133, pp. 38, figs. 6. June, 1922.)

Fattening steers. E. L. Potter and R. Withycombe. (Oreg. Sta. Bul. 193, pp. 18, figs. 2. Aug., 1922.)

Comparison of shelled corn, rice meal, and velvet beans for fattening steers. L. V. Starkey and W. D. Salmon. (S. C. Sta. Bul. 214, pp. 8, fig. 1. Sept., 1922.)

Sunflower silage for steers.—Smutted corn silage for pregnant cows. J. W. Wilson and A. H. Kuhlman. (S. Dak. Sta. Bul. 199, pp. 470–482. June, 1922.)

Grain sorghums versus corn for fattening baby beeves. J. M. Jones, R. A. Brewer, and R. E. Dickson. (Tex. Sta. Bul. 296, pp. 25. May, 1922.)

SHEEP

Care and management of sheep on the farm. W. E. Joseph. (Mont. Sta. Circ. 105, pp. 29, figs. 12. May, 1922.)

Sheep feeding investigation, 1920–21. A. M. Paterson and H. B. Winchester (Kans. Sta. Circ. 96, pp. 7, fig. 1. Sept., 1922.)

Breeding experiments with Kentucky mountain ewes. L. J. Horlacher and E. S. Good. (Ky. Sta. Bul. 243, pp. 139–199, figs. 69. July, 1922.)

Wintering breeding ewes. A. E. Darlow. (Okla. Sta. Bul. 142, pp. 8. Mar., 1922.)

Winter rations for breeding ewes. J. W. Hammond. (Ohio Sta. Bul. 358, pp. 125–196, figs. 16. May, 1922.)

Lamb feeding experiments. C. W. Hickman and E. F. Rinehart. (Idaho Sta. Circ. 29, pp. 8, fig. 1 Sept., 1922.)

Lamb feeding experiments. H. Hackedorn, R. P. Bean, and J. Sotola. (Wash. Col. Sta. Bul. 170, pp. 24, fig. 1. Aug., 1922.)

Sheep feeding.—XI, Fattening western lambs. J. H. Skinner and F. G. King. (Ind. Sta. Bul. 263, pp. 15. June, 1922.)

One-night camps vs. established bed grounds on Nevada sheep ranges. C. E. Fleming. (Nev. Sta. Bul. 103, pp. 21, figs. 9. Aug., 1922.)

Effects of alkali and weathering upon the wool of range sheep. J. A. Hill. (Wyo. Sta. Bul. 131, pp. 16. Mar., 1922.)

The regain of unwashed wool. J. A. Hill. (Wyo. Sta. Bul. 132, pp. 35–54. June, 1922.)

SWINE

Hog feeding experiments. H. Hackedorn and J. Sotola. (Wash. Col. Sta. Bul. 169, pp. 32, figs. 2. Aug., 1922.)

Feeding and management of breeding swine. W. E. Joseph. (Mont. Sta. Circ. 107, pp. 21, figs. 14. July, 1922.)

Saving the orphan pigs. J. M. Evvard and G. V. Glatfelter. (Iowa Sta. Circ. 80, pp. 11. Nov., 1922.)

Feeding the brood sow. J. M. Evvard and C. C. Culbertson. (Iowa Sta. Circ. 81, pp. 4. Nov., 1922.)

Methods and cost of raising pigs to the weaning age. D. T. Gray and E. H. Hostetler. (N. C. Sta. Bul. 244, pp. 15, figs. 3. July, 1922.)

Rations for weanling pigs. L. V. Starkey and W. D. Salmon. (S. C. Sta. Bul. 213, pp. 8. Aug., 1922.)

Effect of protein and mineral on the development of swine. C. P. Thompson. (Okla. Sta. Bul. 144, pp. 27, figs. 9. May, 1922.)

Hogging down crops.—Cost of producing crops and pork. A. F. Kidder and W. H. Dalrymple. (La. Stas. Bul. 187, pp. 19. Feb., 1923.)

Self-feeders for swine. J. M. Evvard, J. B. Davidson, and W. A. Foster. (Iowa Sta. Bul. 208, pp. 97–143, figs. 50. Nov., 1922.)

Self-feeders for swine. J. M. Evvard, J. B. Davidson, and W. A. Foster. (Iowa Sta. Bul. 208, abridged ed., pp. 32, figs. 26. Nov., 1922.)

The northern pig from birth to market. J. H. Shepperd. (N. Dak. Sta. Bul. 156, pp. 28, figs. 11. Apr., 1922.)

Finishing pigs for market. A. W. Oliver and E. L. Potter. (Oreg. Sta. Bul. 196, pp. 20. Jan., 1923.)

Swine publications and associations. J. M. Evvard and A. L. Anderson. (Iowa Sta. Circ. 79, pp. 8. July, 1922.)

POULTRY

Breeding Rhode Island Reds for type and egg production. H. A. Bittenbender. (Iowa Sta. Bul. 202, pp. 9–24, figs. 21. Jan., 1922.)

Selection of breeders without the trapnest. W. H. Allen. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 1, pp. 4. Oct., 1922.)

The winter-time management of the laying flock. W. C. Thompson. (N. J. Stas. Circ. 145, pp. 32, figs 28. Nov., 1922.)

Changes in egg production in the station flock. H. D. Goodale and R. Sanborn. (Mass. Sta. Bul. 211, pp. 99–125, figs. 16. Oct., 1922.)

Egg production and costs on New Jersey poultry farms. W. H. Allen. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 4, pp. 4. Jan., 1923.)

Effect of confinement and green feed on number and hatchability of eggs. H. Atwood. (W. Va. Sta. Bul. 178, pp. 12. Aug., 1922.)
The relationship between the weight and the hatching quality of eggs. L. C. Dunn. (Conn. Storrs Sta. Bul. 109, pp. 91–114. Mar., 1922.)
Poultry feeding. J. E. Dougherty. (Calif. Sta. Circ. 242, pp. 22, fig. 1. May, 1922.)
Relative value of certain protein feeds for egg production. R. T. Parkhurst. (Idaho Sta. Circ. 27, pp. 8, fig. 1. Aug., 1922.)
Feeding the laying flocks. W. C. Thompson. (N. J. Stas. Hints to Poultrymen, vol. 10, No. 12, pp. 4. Sept., 1922.)
The use of artificial light to increase winter egg production. J. E. Dougherty. (Calif. Sta. Circ. 254, pp. 6, fig. 1. Nov., 1922.)
Brooding the chicks. W. P. Thorp, jr. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 7, pp. 4, fig. 1. Apr., 1923.)
Baby chick troubles. G. H. Pound. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 5, pp. 4, fig. 1. Feb., 1923.)
Oregon experiment station trap-nest. A. G. Lunn and F. L. Knowlton. (Oreg. Sta. Circ. 33, pp. 4, figs. 5. Jan., 1923.)
Correlation between external body characters and annual egg production in White Leghorn fowls. R. M. Sherwood. (Tex. Sta. Bul. 295, pp. 14. May, 1922.)
Culling farm poultry. L. F. Payne. (Kans. Sta. Circ. 93, pp 34, figs. 23. May, 1922.)
Methods for the exhibitor. G. W. Hervey. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 2, pp. 4, fig. 1. Nov., 1922.)
Poultry meat production. P. A. Hayden. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 8, pp. 4. May, 1923.)
Report of egg laying contests for 1922. R. R. Hannas and F. H. Clickner. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 3, pp. 4. Dec., 1922.)
Raising ducks and geese on New Jersey farms. W. C. Thompson. (N. J. Stas. Hints to Poultrymen, vol. 10, No. 11, pp. 4, fig. 1. Aug., 1922.)
Methods of preserving eggs. C. B. Swingle and G. E. Pool. (Mont. Sta. Circ. 111, pp. 8. Jan., 1923.)

MISCELLANEOUS

Livestock judging contests. J. H. Shepperd. (North Dakota Sta. Bul. 157, pp. 31, figs. 4. Apr., 1922.)

DAIRYING

The college dairy herd.—Development, care, and management. J. O. Tretsven. (Mont. Sta. Bul. 145, pp. 24, figs. 8. Nov., 1921.)
Raising dairy cattle. J. O. Tretsven. (Mont. Sta. Circ. 104, pp. 20, figs. 14, Mar., 1922.)
Feeding and managing dairy cows in Montana. J. O. Tretsven. (Mont. Sta. Circ. 106, pp. 16, figs. 9. June, 1922.)
Dairying in Porto Rico. D. W. May. (Porto Rico Sta. Bul. 29, pp. 19, pls. 4. Dec., 1922.)
Influence of purebred dairy sires. T. M. Olson and G. C. Biggar. (S. Dak. Sta. Bul. 198, pp. 433–467, figs. 33. June, 1922.)
The protein requirements of dairy cows. J. L. Hills et al. (Vt. Sta. Bul. 225, pp. 199. June, 1922.)
The maintenance requirements of dairy cattle. J. L. Hills. (Vt. Sta. Bul. 226. pp. 191. June, 1922.)
The protein and the maintenance requirements of dairy cattle. J. L. Hills. (Vt. Sta. Bul. 229, pp. 9. Oct., 1922.)
Growth studies of dairy heifers.—Effect of light and heavy feeding of wide and narrow rations. (Nebr. Sta. Bul. 181, pp. 22, figs. 5. Aug., 1922.)
Growth studies of dairy heifers.—II, Protein requirements for growing heifers. (Nebr. Sta. Bul. 184, pp. 18. Jan., 1923.)
Sunflower silage for milk production. S. I. Bechdel. (Pa. Sta. Bul. 172, pp. 16. Mar., 1922.)
Silage feeding investigations for milk production. S. I. Bechdel. (Pa. Sta. Bul. 178, pp. 23. Feb., 1923.)
Comparison of corn ensilage and sunflower ensilage for dairy cows. W. L. Quayle. (Wyo. Sta. State Farms Bul. 3, pp. 11, fig. 1. Sept., 1922.)
Soy beans as a home-grown supplement for dairy cows. A. C. McCandlish, E. Weaver, and L. A. Lunde. (Iowa Sta. Bul. 204, pp. 47–52. Feb., 1922.)
The mineral metabolism of the milch cow. E. B. Forbes et al. (Ohio Sta. Bul. 363, pp. 59, figs. 3. Sept., 1922.)
Studies in milk secretion.—XVII, Relation between milk yields and butter-fat percentages of the 7 day and 365 day tests of Holstein-Friesian advanced registry cattle. M. S. Gowen and J. W. Gowen. (Me. Sta. Bul. 306, pp. 21–60. June, 1922.)
Influence of age at the time of freshening on production of dairy cows. A. C. McCandlish. (Iowa Sta. Research Bul. 73, pp. 243–255. Aug., 1922.)
Germ content of milk as influenced by visible dirt. H. A. Harding and M. J. Prucha. (Ill. Sta. Bul. 236, abs., pp. 4. Dec., 1921.)
Comparative expense of mechanical and hand milking. F. A. Pearson and H. A. Ross. (Ill. Sta. Bul. 241, pp. 493–506. Jan., 1923.)
Practical suggestions for sterilizing milking machine tubes. J. D. Luckett. (N. Y. State Sta. Bul. 492, pop. ed., pp. 8. May, 1922.)
Studies on ropiness in cultures of *Streptococcus lactis*. B. W. Hammer. (Iowa Sta. Research Bul. 74, pp. 259–270. Jan., 1923.)
Influence of acidity on flavor and keeping quality of butter. M. Mortensen. (Iowa Sta. Bul. 207, pp. 87–96, fig. 1. Aug., 1922.)
The clarification of milk for cheese making, W. W. Fisk and W. V. Price. (N. Y. Cornell Sta. Bul. 418, pp. 14, figs. 6. Apr., 1923.)
Cheese pests and their control. E. R. De-Ong and C. L. Roadhouse. (Calif. Sta. Bul. 343, pp. 399–424, figs. 9. May, 1922.)
Review of the bacteriological aspects of cheese ripening. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 89, pp. 36. Apr., 1922.)
The types of bacteria found in commercial cheddar cheese. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 90, pp. 38. Apr., 1922.)
Milk testing in practice. H. M. Jones and T. H. Wright. (S. Dak. Sta. Bul. 197, pp. 418–431, figs. 12. June, 1922.)
California State dairy cow competition, 1920–22. F. W. Woll. (Calif. Sta. Bul. 351, pp. 185–244, figs. 15. Nov., 1922.)
Official testing of dairy cattle in Oregon. H. N. Colman. (Oreg. Sta. Circ. 41, pp. 38. (May, 1923.)
Why costs of milk vary.—Possibilities of cow testing associations. P. E. McNall and D. R. Mitchell. (Wis. Sta. Bul. 345, pp. 24, figs. 4. Sept., 1922.)

DISEASES OF LIVESTOCK

Bovine infectious abortion and associated diseases of cattle and new-born calves. G. H. Hart, J. Traum, and F. M. Hayes. (Calif. Sta. Bul. 353, pp. 271–397, figs. 12. Jan., 1923.)
The practical control of infectious abortion in cattle. J. W. Connaway. (Mo. Sta. Bul. 201, pp. 11. Feb., 1923.)
Infectious abortion of cattle. B. T. Simms and F. W. Miller. (Oreg. Sta. Bul. 192, pp. 12, fig. 1. Nov., 1922.)
An experimental study of infectious abortion in swine. F. B. Hadley and B. A. Beach. (Wis. Sta. Research Bul. 55, pp. 35, figs. 4. Sept., 1922.)
Abortion disease in Wyoming. C. Elder. (Wyo. Sta. Circ. 18, pp. 6. July, 1922.)
Bacteriology and pathology of sterility in cattle. D. C. Beaver. (Minn. Sta. Tech. Bul. 5, pp. 91, pls. 12. May, 1922.)
The serum treatment of hog cholera. R. Graham. (Ill. Sta. Circ. 261, pp. 11, figs. 3. June, 1922.)
Studies of immunity against hemorrhagic septicemia. L. Van Es and H. M. Martin. (Nebr. Sta. Research Bul. 21, pp. 38, figs. 2. Aug., 1922.)
Insect transmission of swamp fever or infectious anemia of horses. J. W. Scott. (Wyo. Sta. Bul. 133, pp. 55–137, figs. 31. June, 1922.)
Poisonous action of red buckeye on horses, mules, cattle, hogs, and fish. D. T. Cary. (Ala. Sta. Bul. 218, pp. 20. June, 1922.)
Blackleg in cattle. H. Welch. (Mont. Sta. Circ. 110, pp. 8, figs. 5. Jan., 1923.)
Johne's disease, a cattle menace. B. A. Beach and E. G. Hastings. (Wis. Sta. Bul. 343, pp. 22, figs. 6. May, 1922.)
Twenty-two years of tuberculin testing in the same herd. A. C. Dahlberg. (N. Y. State Sta. Bul. 496, pp. 8. Jan., 1923.)
Second preliminary report on parasites found in ruminants at the municipal abattoir, Baton Rouge, La. G. Dikmans. (La. Stas. Tech. Bul. 186, pp. 12. Jan.. 1923.)
Recommendations concerning the common diseases and parasites of poultry in California. J. R. Beach and S. B. Freeborn. (Calif. Sta. Circ. 251, pp. 44, figs. 34. Aug., 1922.)
The common animal parasites of swine. R. Graham and I. B. Boughton. (Ill. Sta. Circ. 269, pp. 18, figs. 11. May, 1923.)
The common intestinal roundworm of swine. H. M. Martin. (Nebr. Sta. Circ. 17, pp. 11, figs. 3. June, 1922.)
The colon-typhoid intermediates as causative agents of disease in birds.—II, Atypical organisms. H. G. May and H. A. M. Tibbetts. (R. I. Sta. Bul. 191, pp. 42. Jan., 1923.)
Control of bacillary white diarrhea, 1920–21. G. E. Gage. (Mass. Sta. Control Ser. Bul. 18, pp. 8. Mar., 1922.)
Control of bacillary white diarrhea, 1921–22. G. E. Gage and O. S. Flint. (Mass. Sta. Control Ser. Bul. 22, pp. S. Dec., 1922.)
Concerning the diagnosis of *Bacterium pullorum* infection in the domestic fowl. G. E. Gage. (Mass. Sta. Tech. Bul. 5, pp. 61–88, pl. 1, figs. 4. Aug., 1922.)
Roup in fowls. A. J. Durant. (Mo. Sta. Bul. 196, pp. 12, figs. 2. Sept., 1922.)
Roup in poultry. J. E. Guberlet. (Okla. Sta. Circ. 51, pp. 3. [1923.])
The rose chafer as a cause of death of chickens. G. H. Lamson, jr. (Conn. Storrs Sta. Bul. 110, pp. 117–134, figs. 10. Oct., 1922.)
The preparation of laboratory specimens as an aid to the diagnosis of animal diseases. L. Vanes and L. V. Skidmore. (Nebr. Sta. Circ. 16, pp. 14, figs. 6. June, 1922.

AGRICULTURAL ENGINEERING

Clearing cut-over lands in Baldwin County. E. C. Easter and M. L. Nichols. (Ala. Sta. Circ. 45, pp. 4. June, 1922.)
Stump land reclamation in Oregon. H. D. Scudder. (Oreg. Sta. Bul. 195, pp. 62, figs. 40. Dec., 1922.)
Measurement of irrigation water on the farm. H. A. Wadsworth. (Calif. Sta. Circ. 250, pp. 36, figs. 17. July, 1922.)
The measurement of water.—A hand book for ditch riders and water users. W. G. Steward. (Idaho Sta. Bul. 127, pp. 32, figs. 19. Jan., 1922.)
Duty-of-water investigations on Coal Creek, Utah. A. Fife. (Utah Sta. Bul. 181, pp. 22, figs. 11. Aug., 1922.)
The net duty of water in Sevier Valley. O. W. Israelson and L. M. Winsor. (Utah Sta. Bul. 182, pp. 36, figs. 5. July, 1922.)
Return of seepage water to the lower South Platte River in Colorado. R. L. Parshall. (Colo. Sta. Bul. 279, pp. 72, pl. 1, figs. 23. Dec., 1922.)
Drainage and improvement of white land and similar wet land. W. L. Powers. (Oreg. Sta. Circ. 47, pp. 8, figs. 2. June, 1923.)
An outlet drain for every farm. E. R. Jones and O. R. Zeasman. (Wis. Sta. Bul. 351, pp. 55, figs. 22. Dec., 1922.)
Additional instructions for laying out and constructing the Mangum terrace. P. Bain, jr. (Mo. Sta. Circ. 98, Sup., pp. 2. Feb., 1922.)
Tractor situation in Alabama. W. L. Nichols and J. W. Randolph. (Ala. Sta. Circ. 46, pp. 7, fig. 1. Dec., 1922.)
A study of sidedraft and tractor hitches. A. H. Hoffman. (Calif. Sta. Bul. 349, pp. 113–163, figs. 78. Oct., 1922.)
The gas tractor in Montana. H. E. Selby. (Mont. Sta. Bul. 151, pp. 24, figs. 3. Dec., 1922.)
The farm tractor in Mason and Berkeley Counties. A. J. Dadisman, J. H. Shaffer, and F. D. Cornell. (W. Va. Sta. Bul. 180, pp. 12, figs. 4. Oct., 1922.)
Farm homes. (Wis. Sta. Bul. 353, pp. 24, figs. 15. Jan., 1923.)
Cattle feeding barns and shelters. W. A. Foster and R. S. Stephenson. (Iowa Sta. Circ. 74, pp. 23, pls. 2, figs. 25. May, 1922.)
Beef cattle equipment. W. A. Foster and R. S. Stephenson. (Iowa Sta. Circ. 75, pp. 31, figs. 28. May, 1922.)
The New Jersey suburban unit house. W. P. Thorp, jr. (N. J. Stas. Hints to Poultrymen, vol. 10, No. 10, pp. 4, figs. 6. July, 1922.)
New Jersey poultry houses. W. C. Thompson, W. P. Thorp, jr., and G. H. Pound. (N. J. Stas. Bul. 370, pp. 56, figs. 39. Jan., 1923.)
Plans and specifications for New Jersey poultry buildings. W. C. Thompson, W. P. Thorp, jr., and G. H. Pound. (N. J. Stas. Circ. 152, pp. 16, figs. 13. Apr., 1923.)
The Missouri colony brooder house. H. L. Kempster. (Mo. Sta. Circ. 110, pp. 2, figs. 3. Feb., 1923.)
The farm septic tank. J. C. Wooley and W. M. Gibbs. (Idaho Sta. Bul. 128, pp. 18, figs. 12. Jan., 1922.)
The durability of fence posts. J. C. Wooley. (Mo. Sta. Circ. 108, pp. 4, figs. 2. Dec., 1922.)
Heat transmission of commercial wallboard. G. A. Cumings. (Colo. Sta. Bul. 282, pp. 8, figs. 5. Jan., 1923.)
Methods of handling hay in Colorado. G. A. Cumings. (Colo. Sta. Bul. 281, pp. 39, figs. 44. Jan., 1923.)

RURAL ECONOMICS AND EDUCATION

Cost of production and farm organization. R. E. Willard, H. Metzger, and T. S. Thorfinnson. (N. Dak. Sta. Bul. 165, pp. 129, figs. 8. Dec., 1922.)

Preliminary report.—Business analysis of 181 general crop, 11 dairy, and 10 fruit farms, Twin Falls County, Idaho, 1921. B. Hunter. (Idaho Sta. Bul. 132, pp. 19. Feb., 1923.)

The cost of producing milk, and dairy farm organization in western Washington. G. Severance and E. R. Johnson. (Wash. Col. Sta. Bul. 173, pp. 50, figs. 3. Nov., 1922.)

An economic study of dairying on 149 farms in Broome County, New York. E. G. Misner. (N. Y. Cornell Sta. Bul. 409, pp. 271–443, figs. 22. Apr., 1922.)

An economic study of the production of canning crops in New York. L. J. Norton. (N. Y. Cornell Sta. Bul. 412, pp. 82, figs. 6. Dec., 1922.)

Fifty years of farmers' elevators in Iowa. E. G. Nourse. (Iowa Sta. Bul. 211, pp. 233–271, figs. 10. Mar., 1923.)

Farmers' cooperation in Minnesota, 1917–1922. H. B. Price. (Minn. Sta. Bul. 202, pp. 78, figs. 9. Jan., 1923.)

Accounting records for live-stock shipping associations. F. Robotka. (Iowa Sta. Bul. 209, pp. 145–200, pls. 5, figs. 12. Nov., 1922.)

Organization and management of local live stock shipping associations in Minnesota. E. W. Gaumnitz and J. D. Black. (Minn. Sta. Bul. 201, pp. 77, figs. 12. Dec., 1922.)

Cooperative live stock shipping associations in Missouri. R. Loomis. (Mo. Sta. Bul 199, pp. 10. Jan., 1923.)

Marketing by cooperative sales companies. T. Macklin. (Wis. Sta. Bul. 346, pp. 32, figs. 10. Jan., 1923.)

Preliminary study of the methods and means of handling fresh produce in Rhode Island. H. B. Hall. (R. I. Sta. Bul. 192, pp. 28, figs. 2. Jan., 1923.)

The marketing of Kentucky strawberries. O. B. Jesness and D. B. Card. (Ky. Sta. Bul. 246, pp. 30, figs. 4. Jan., 1923.)

Farm storage as a factor in the marketing of Kansas wheat. R. M. Green. (Kans. Sta. Bul. 229, pp. 32, figs. 6. Nov., 1922.)

Marketing Vermont maple-sap products. A. W. McKay. (Vt. Sta. Bul. 227, pp. 48, figs. 8. July, 1922.)

Sale prices as a basis for farm land appraisal. G. C. Haas. (Minn. Sta. Tech. Bul. 9, pp. 31, figs. 2. Nov., 1922.)

Land prices and land speculation in the bluegrass region of Kentucky. G. W. Forster. (Ky. Sta. Bul. 240, pp. 39–74, figs. 4. Jan., 1922.)

Wages of farm labor. C. L. Holmes. (Minn. Sta. Tech. Bul. 4, pp. 65, figs. 12. May, 1922.)

Purchasing power of Nebraska grains. H. C. Filley and E. A. Frerichs. (Nebr. Sta. Bul. 187, pp. 35, figs. 4. Mar., 1923.)

Prices of farm products in New York. G. F. Warren. (N. Y. Cornell Sta. Bul. 416, pp. 63, figs. 16. Jan., 1923.)

Factors determining the price of potatoes in St. Paul and Minneapolis. H. Working. (Minn. Sta. Tech. Bul. 10, pp. 41, figs. 8. Oct., 1922.)

New York City egg prices and what they mean to the poultry raisers of New Jersey. H. Keller, jr. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 6, pp. 4. Mar., 1923.)

Rural organization. A study of primary groups in Wake County, N. C. C. C. Zimmerman and C. C. Taylor. (N. C. Sta. Bul. 245, pp. 42, figs. 9. Aug., 1922.)

The Nebraska farm family.—Some land tenure phases. J. O. Rankin. (Nebr. Sta. Bul. 185, pp. 31, figs. 9. Feb., 1923.)

An economic study of a typical ranching area on the Edwards Plateau of Texas. B. Youngblood and A. B. Cox. (Tex. Sta. Bul. 297, pp. 437, figs. 73. July, 1922.)

Colonization and rural development in California. E. Mead, C. F. Shaw, R. L. Adams, and J. W. Gregg. (Calif. Sta. Circ. 247, pp. 72, figs. 13. June, 1922.)

Reading matter in Nebraska farm homes. J. O. Rankin. (Nebr. Sta. Bul. 180, pp. 28, figs. 9. June, 1922.)

Outlines of course of instruction in agricultural nature study for the rural schools of California. O. J. Kern. (Calif. Sta. [Pamphlet], pp. 106, figs. 60. Feb., 1923.)

Bread club manual. K. G. Van Aken and H. M. Phillips. (Ill. Sta. Circ. 262, pp. 35, figs. 12. June, 1922.)

The organization and direction of clothing clubs. H. M. Phillips and F. Mallory. (Ill. Sta. Circ. 263, pp. 30, figs. 7. June, 1922.)

Clothing club manual. M. C. Whitlock and H. M. Phillips. (Ill. Sta. Circ. 264, pp. 88, figs. 65. Oct., 1922.)

REPORTS, PERIODICALS, REGULATORY PUBLICATIONS, PUBLICATION LISTS, AND MISCELLANEOUS

REPORTS

Report of the Alaska Agricultural Experiment Stations, 1921. C. C. Georgeson et al. pp. 58, pls. 12.

Thirty-second annual report of the [Arizona] Agricultural Experiment Station for the year ended June 30, 1921. D. W. Working et al. pp. 541–616, figs. 9.

Farm helps from experiments.—Annual report of the director, 1921–22. B. Knapp. (Ark. Sta. Bul. 181, pp. 103, figs. 36. June, 1922.)

Report of the director of the agricultural experiment station, 1922. C. M. Haring. (Rpt. Col. Agr. and Agr. Expt. Sta., Univ. California, 1922, pp. 15–255, pls. 2, figs. 62.)

Thirty-fifth annual report of the [Colorado] Agricultural Experiment Station, 1922. C. P. Gillette et al. pp. 30.

Forty-fifth annual report of the Connecticut [State] Agricultural Experiment Station, being the annual report for the year ending October 31, 1921. E. H. Jenkins et al. pp. 445, pls. 31, figs. 11.

Report of the director for the year ending October 31, 1922. E. H. Jenkins. (Conn. State Sta. Bul. 243, pp. 167–180. Nov., 1922.)

Annual report of the director for the fiscal year ending June 30, 1922. C. A. McCue et al. (Del. Sta. Bul. 133, pp. 36, figs. 7. Nov., 1922.)

University of Florida Agricultural Experiment Station report for the fiscal year ending June 30, 1921. W. Newell et al. pp. 33R + III.

Thirty-fifth annual report, Georgia Experiment Station, for the year 1922. H. P. Stuckey. pp. 30, figs. 6.

Georgia Coastal Plain Experiment Station, Tifton, Ga., first annual report, 1920. S. H. Starr. (Ga. Coastal Plain Sta. Bul. 1, pp. 22, figs. 11. June, 1921.)

Georgia Coastal Plain Experiment Station, Tifton, Ga., second annual report, 1921. S. H. Starr. (Ga. Coastal Plain Sta. Bul. 2, pp. 30, figs. 14. June, 1922.)

Report of the Guam Agricultural Experiment Station, 1921. C. W. Edwards et al. pp. 43, pls. 6.

Biennial report of the director of the agricultural experiment station for 1921 and 1922. E. J. Iddings. (Idaho Sta. Circ. 30, pp. 15. Jan., 1923.)

Thirty-fourth annual report, Agricultural Experiment Station, University of Illinois, 1920–21. E. Davenport. pp. 20.

Thirty-fifth annual report, Agricultural Experiment Station, University of Illinois, 1921–22. E. Davenport. pp. 24.

Thirty-fifth annual report of the Purdue University Agricultural Experiment Station, Lafayette, Ind., for the year ending June 30, 1922. G. I. Christie and H. J. Reed. pp. 68, figs. 35.

Annual report for fiscal year ending June 30, 1921, Agricultural Experiment Station Iowa State College of Agriculture and Mechanic Arts. C. F. Curtiss and P. E. Brown. pp. 64.

Work of the Kansas Agricultural Experiment Station during the biennium ending June 30, 1922.—Director's report 1920–1922. F. D. Farrell. pp. 45, figs. 5.

Thirty-third annual report of the Kentucky Agricultural Experiment Station for the year 1920, Part II. pp. 320 + 15, pls. 12, figs. 31.

Thirty-fourth annual report of the Agricultural Experiment Station of the University of Kentucky for the year 1921, Part I. T. Cooper. pp. 53.

Thirty-fourth annual report of the Kentucky Agricultural Experiment Station for the year 1921, Part II. pp. 505 + 34 + IV, figs. 49.

Thirty-fifth annual report of the Agricultural Experiment Station of the University of Kentucky for the year 1922, Part I. T. Cooper. pp. 61.

Abstracts of papers not included in bulletins; finances; meteorology; index. (Me. Sta. Bul. 304, pp. 345–372 + XII. Dec., 1921.)

The thirty-fifth annual report of the University of Maryland Agricultural Experiment Station, 1922. H. J. Patterson et al. pp. XVI + 249, figs. 78.

Thirty-fourth annual report of the Massachusetts Agricultural Experiment Station [1921], Parts I and II. S. B. Haskell et al. pp. 79a + 179, pls. 5, figs. 12.

Thirty-fourth annual report of the Experiment Station of the Michigan Agricultural College for the year ending June 30, 1921. R. S. Shaw et al. pp. 151–636, figs. 99.

Mississippi Agricultural Experiment Station, thirty-fifth annual report for the fiscal year ending June 30, 1922. J. R. Ricks et al. pp. 59.

New Knowledge.—One year's work, agricultural experiment station. Report of the director for the year July 1, 1921, to June 30, 1922. F. B. Mumford et al. (Mo. Sta. Bul. 197, pp. 95, figs. 17. Dec., 1922.)

Twenty-eighth annual report [Montana Agricultural Experiment Station] for the fiscal year ending June 30, 1921. F. B. Linfield et al. pp. 94, figs. 40.

Thirty-fifth annual report of the agricultural experiment station of Nebraska [1921]. E. A. Burnett and W. W. Burr. pp. 58.

Progress of agricultural experiments, 1922.—A report of the director of the New Hampshire Agricultural Experiment Station for the year 1922, including a financial statement for the fiscal year ending June 30, 1922. [J. C. Kendall.] (N. H. Sta. Bul. 208, pp. 31, Jan., 1923.)

Forty-second annual report of the New Jersey State Agricultural Experiment Station and the thirty-fourth annual report of the New Jersey Agricultural Experiment Station for the year ending June 30, 1921. J. G. Lipman et al. pp. XXXI + 475, pls. 18, figs. 12.

Thirty-third annual report, Agricultural Experiment Station of the New Mexico College of Agriculture and Mechanic Arts, 1922. F. Garcia. pp. 52, figs. 4.

Thirty-fifth annual report of the New York State College of Agriculture at Cornell University and of the Agricultural Experiment Station, 1922. A. R. Mann. pp. 73.

Forty-first annual report [New York State Agricultural Experiment Station] with the director's report for 1922. R. W. Thatcher. pp. 51.

Experiment station progress.—Report of the director, 1920–21. P. F. Trowbridge. (N. Dak. Sta. Bul. 159, pp. 44, figs. 6, Apr., 1922.)

Forty-first annual report of the Ohio Agricultural Experiment Station for the year ended June 30, 1922. C. G. Williams. (Ohio Sta. Bul. 362, pp. LIX + 5, figs. 8. June, 1922.)

Thirtieth annual report [Oklahoma Agricultural Experiment Station], 1921. C. T. Dowell. pp. 32, figs. 3.

New facts for Oklahoma farmers.—Thirty-first annual report, year ending June 30, 1922. C. T. Dowell. pp. 29.

Director's biennial report, Oregon Agricultural Experiment Station, 1920–1922. J. T. Jardine. pp. 104.

Annual report of the director for the year ending June 30, 1922. [R. L. Watts.] (Pa. Sta. Bul. 176, pp. 22. Oct., 1922.)

Thirty-fourth annual report of the director of the [Rhode Island] Agricultural Experiment Station, 1921. B. L. Hartwell. pp. 13.

Thirty-fifth annual report of the director [1922]. B. L. Hartwell. (R. I. Sta. Bul. 193, pp. 16. Feb., 1923.)

Thirty-fifth annual report of the South Carolina Experiment Station of the Clemson Agricultural College for the year ended June 30, 1922. H. W. Barre. pp. 72, figs. 23.

Annual report of the director South Dakota Agricultural Experiment Station for the fiscal year ending June 30, 1922. J. W. Wilson et al. pp. 32.

Thirty-fourth annual report [Texas Agricultural Experiment Station], 1921. B. Youngblood. pp. 48.

Report of the Virgin Islands Agricultural Experiment Station, 1921. L. Smith et al. pp. 24, pls. 3.

Thirty-second annual report for the year ending June 30, 1922. E. C. Johnson et al. (Wash. Col. Sta. Bul. 175, pp. 62, figs. 2. Dec., 1922.)

Science serves Wisconsin farms.—Annual report of the director, 1921–1922. H. L. Russell and F. B. Morrison. (Wis. Sta. Bul. 352, pp. 122, figs. 54. Feb., 1923.)

Thirty-second annual report of the University of Wyoming Agricultural Experiment Station, 1921–1922. J. A. Hill et al. pp. 143–170.

Report of the Northeast Demonstration Farm and Experiment Station, Duluth. [Minnesota], 1921. M. J. Thompson. pp. 34, figs. 9.

Report of the Northwest Experiment Station, Crookston [Minnesota], 1921. C. G. Selvig. pp. 76.

Report of West Central Experiment Station, Morris [Minnesota], 1921. P. E. Miller. pp. 43.

Report from Holly Springs Branch Experiment Station for 1922. C. T. Ames. (Miss. Sta. Bul. 211, pp. 16, figs. 3. Dec. 1922.)

Report from Raymond Branch Experiment Station for 1920 to 1922 inclusive. C. B. Anders. (Miss. Sta. Bul. 213, pp. 6. Jan., 1923.)

Williston substation report for years 1914 to 1920. C. H. Ruzicka. (N. Dak. Sta. Bul. 158, pp. 104, figs. 16. May, 1922.)

Report of the Dickinson Substation, 1920–21. L. Moomaw. (N. Dak. Sta. Bul. 160, pp. 32, figs. 4. May, 1922.)

Report of the Edgeley Substation, year ending June 30, 1921. O. A. Thompson. (N. Dak. Sta. Bul. 161, pp. 12. May, 1922.)

The demonstration farms.—Sixteenth annual report year ending June 30, 1921. E. I. Olsen. (N. Dak. Sta. Bul. 163, pp. 54. May, [1922.])

Facts about College of Agriculture, University of Arkansas. (Ark. Sta. Bul. 182, pp. 31, figs. 24. Dec., 1922.)

The agriculture of the Upper Peninsula.—Its present development and possibilities. J. W. Weston, D. L. McMillan, and G. W. Putnam. (Mich. Sta. Spec. Bul. 116, pp. 82, figs. 50. Apr., 1922.)

The Mississippi agricultural experiment stations.—An historical sketch. J. W. Bailey. (Miss. Sta. Bul. 216, pp. 56. Mar., 1923.)

100 worth while accomplishments of the College of Agriculture the past two years. (Nebr. Sta. Circ. 18, pp. 12. Dec., 1922.)

State wide activities of the College of Agriculture. (Nebr. Sta. Circ. 19, pp. 13, figs. 11. Jan., 1923.)

The rise, development, and value of the agricultural experiment station. J. T. Jardine. (Oreg. Sta. Circ. 26, pp. 38, figs. 20. Sept., 1922.)

PERIODICALS

Quarterly Bulletin, Michigan Agricultural Experiment Station—
- Vol. 5 (1922), No. 1, pp. 46, figs. 18; No. 2, pp. 49–86, figs. 16; No. 3, pp. 93–153, figs. 20; No. 4, pp. 155–200, figs. 9.

Farmers' Market Bulletin, North Carolina Agricultural Experiment Station—
- Vol. 9 (1922), No. 53, pp. 9, figs. 2; No. 54, pp. 8, fig. 1. No. 55, pp. 8, figs. 2; No. 56, pp. 8; No. 57, pp. 11; No. 58, pp. 8.
- Vol. 10 (1923), No. 59, pp. 8; No. 60, pp. 8; No. 61, pp. 8; No. 62, pp. 8.

Monthly Bulletin, Ohio Agricultural Experiment Station—
- Vol. 7 (1922), No. 5–6, pp. 73–104, figs. 7; No. 7–8, pp. 105–136, figs. 13; No. 9–10, pp. 137–168, figs. 8; No. 11–12, pp. 169–215, figs. 25.
- Vol. 8 (1923), No. 1–2, pp. 32, figs. 9; No. 3–4, pp. 33–64, figs. 6.

Bi-monthly Bulletin, Western Washington Experiment Station, Puyallup, Wash.—
- Vol. 10 (1922), No. 2, pp. 25–48, figs. 12; No. 3, pp. 49–64, figs. 3; No. 4, pp. 65–88, figs. 5; (1923), No. 5, pp. 89–112; No. 6, pp. 113–136, fig. 1.
- Vol. 11 (1923), No. 1, pp. 24, figs. 9.

REGULATORY PUBLICATIONS—FERTILIZERS

Report on commercial fertilizers, 1922. E. H. Jenkins and E. M. Bailey. (Conn. State Sta. Bul. 241, pp. 55–144. Nov., 1922.)

Commercial fertilizers. E. G. Proulx et al. (Ind. Sta. Bul. 262, pp. 63, figs. 2. May, 1922.)

Analyses of commercial fertilizers. H. E. Curtis, H. R. Allen, and R. H. Ridgell. (Ky. Sta. Bul. 238, pp. 365-505. Dec., 1921.)

Commercial fertilizers, 1922. J. M. Bartlett. (Me. Sta. Off. Insp. 105, pp. 45-76. Oct., 1922.)

Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and R. W. Swift. (Mass. Sta. Control Ser. Bul. 20, pp. 42. Nov., 1922.)

Inspection of lime products used in agriculture. H. D. Haskins, L. S. Walker, and R. W. Swift. (Mass. Sta. Control Ser. Bul. 21, pp. 7, fig. 1. Nov., 1922.)

Testing fertilizers for Missouri farmers, 1922. L. D. Haigh. (Mo. Sta. Bul. 200, pp. 51, fig. 1. Feb. 1923.)

Inspection of commercial fertilizers for 1922. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (N. H. Sta. Bul. 206, pp. 16. Oct., 1922.)

Fertilizer inspections in New Jersey from 1880 to 1921. C. S. Cathcart. (N. J. Stas. Bul. 368, pp. 24, figs. 6. Apr., 1922.)

Analyses of commercial fertilizers, fertilizer supplies and home mixtures. C. S. Cathcart. (N. J. Stas. Bul. 371, pp. 35, fig. 1. Nov., 1922.)

Analyses of commercial fertilizers and ground bone; analyses of agricultural lime, 1922. C. S. Cathcart. (N. J. Stas. Bul. 376, pp. 54, fig. 1. Dec., 1922.)

Fertilizer registrations for 1923. C. S. Cathcart. (N. J. Stas. Bul. 382, pp. 22. Jan., 1923.)

Composition and prices of commercial fertilizers in New York in 1922. L. L. Van Slyke. (N. Y. State Sta. Bul. 499, pp. 12. Mar., 1923.)

Commercial fertilizers. R. H. Robinson. (Oreg. Sta. Circ. 31, pp. 16. Nov., 1922.)

Inspection of fertilizers. P. S. Burgess. (R. I. Sta. Ann. Fert. Circ., 1922, pp. 14. Oct., 1922.)

Analyses of commercial fertilizers. R. N. Brackett and H. M. Stackhouse. (S. C. Sta. Bul. 212, pp. 43. Aug., 1922.)

Commercial fertilizers in 1921–1922. G. S. Fraps and S. E. Asbury. (Tex. Sta. Bul. 298, pp. 23. Aug., 1922.)

REGULATORY PUBLICATIONS—FEEDING STUFFS

Report on commercial feeding stuffs. E. M. Bailey. (Conn. State Sta. Bul. 238, pp. 329–361. Feb., 1922.)

Commercial feeding stuffs, 1921–22. J. M. Bartlett. Me. Sta. Off. Insp. 104, pp. 26–43. Aug., 1922.)

Inspection of commercial feedstuffs. P. H. Smith and E. M. Bradley. (Mass. Sta. Control Ser. Bul. 19, pp. 34. Nov., 1922.)

Inspection of commercial feeding stuffs. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (N. H. Sta. Bul. 205, pp. 51. Aug., 1922.)

Analyses of commercial feeding stuffs and registration for 1922 C. S. Cathcart. (N. J. Stas. Bul. 369, pp. 70. Apr., 1922.)

Inspection of commercial feeds. P. H. Wessels. (R. I. Sta. Ann. Feed Circ., 1922, pp. 16. Apr., 1922.)

Inspection of feeds. P. S. Burgess and J. B. Smith. (R. I. Sta. Ann. Feed Circ., 1923, pp. 12. Apr., 1923.)

Comercial feeding stuffs. B. Youngblood. (Tex. Sta. Bul. 303, pp. 192. Oct. 1922.)

REGULATORY PUBLICATIONS—FOODS AND DRUGS

Twenty-sixth report on food products and fourteenth report on drug products. E. M. Bailey. (Conn. State Sta. Bul 236, pp. 227–300. Jan., 1922.)

Twenty-seventh report on food products and fifteenth report on drug products. Part I. E. M. Bailey. (Conn. State Sta. Bul. 240, pp. 51, figs. 21, Aug., 1922.)

Foods and drugs. J. M. Bartlett. (Me. Sta. Off. Insp. 103, pp. 34. Apr., 1922.)

REGULATORY PUBLICATIONS—SEEDS

Inspection of agricultural seeds. E. G. Proulx et al. (Ind. Sta. Bul. 264, pp 56, fig. 1. Jan., 1923.)

Commercial agricultural seeds, 1922, compiled by W. J. Morse. Insecticides and fungicides, 1922, J. M. Bartlett. (Me. Sta. Off. Insp. 106, pp. 77–99. Dec., 1922.)

Work of the seed inspection laboratory for the year 1921. F. S. Holmes. (Md. Sta. Bul. 249, pp. 189–206. June, 1922.)

Results of seed tests for 1922. M. G. Eastman. (N. H. Sta. Bul. 207, pp. 16 Dec., 1922.)

REGULATORY PUBLICATIONS—MISCELLANEOUS

Commercial fertilizers, commercial feeding stuffs, agricultural seed. J. L. Hills et al. (Vt. Sta. Bul. 228, pp. 32. Sept., 1922.)

Report on commercial insecticides and fungicides. E. M. Bailey, R. E. Andrew, and W. E. Britton. (Conn. State Sta. Bul. 242, pp. 145–165. Nov., 1922.)

Analyses of materials sold as insecticides and fungicides during 1922. C. S. Cathcart and R. L. Willis. (N. J. Stas. Bul. 372, pp. 24. Oct., 1922.)

Eighth annual report of the dairy department creamery license division. R. L. Hammond. (Ind. Sta. Circ. 107, pp. 16, figs. 2. June, 1922.)

Report of the creamery license section, 1918–22. P. E. Bacon. (Ky. Sta. Reg. Ser. 3, pp. 15, fig. 1. Dec., 1922.)

Creamery inspection in New Jersey.—Third annual report. F. C. Button. (N. J. Stas. Circ. 143, pp. 16, figs. 2. June, 1922.)

Eighth report of the Montana grain inspection laboratory. (Mont. Sta. Bul. 149, pp. 24, fig. 1. Nov., 1922.)

The purpose and work of the Montana grain inspection laboratory. W. O. Whitcomb. (Mont. Sta. Circ. 108, pp. 11. Oct., 1922.)

Stallion enrollment.—XI, Report of stallion enrollment work for the year 1922, with lists of stallions and jacks enrolled. (Ind. Sta. Circ. 108, pp. 56, fig. 1. Dec., 1922.)

PUBLICATION LISTS AND MISCELLANEOUS

Periodicals available for reference. (N. Y. State Sta. Circ. 59, pp. 18. [1922.])

Available bulletins. (N. Y. State Sta. Circ. 62, pp. 4. [1922.])

Proposed program of development. (N. Y. State Sta. Circ. 60, pp. 7. [1922.])

List of projects under investigation. (N. Y. State Sta. Circ. 61, pp. 4. [1922.])

Bulletin summary. (Mass Sta. Circ. 68, pp. 6. Apr., 1922.)

Bulletin summary. (Mass. Sta. Circ. 69, pp. 6. Oct., 1922.)

Bulletin summary. (Mass. Sta. Circ. 70, pp. 3. Apr., [1923].)

STATISTICS OF THE STATIONS

By J. I. SCHULTE

For the fiscal year ended June 30, 1923, the total income from all sources reported by the experiment stations was $9,493,653.20, this amount including $1,440,000 Federal funds under the Hatch and Adams Acts and $210,000 appropriated by the Federal Government for the experiment stations in Alaska and the insular possessions. The support received by the stations from within the States included $5,539-077.02 derived from State appropriations or apportionments, $373,977 from fees, $1,050,238.55 from the sale of farm and other products, $112,415.12 from miscellaneous sources and $767,-945.51 carried over as balances from the previous year.

The value of additions to the equipment of the stations during the year was reported as follows:

Buildings	$928, 092. 82
Library	30, 381. 50
Apparatus	101, 025. 75
Farm implements	130, 908. 35
Livestock	120, 988. 85
Miscellaneous	148, 165. 61
Total	1, 459, 562. 88

In the work of administration and inquiry the experiment stations employed 2,259 persons. Of these 1,121 were also members of the teaching staffs of the colleges and 462 assisted in the various lines of extension work. During the year the stations issued 920 publications, including annual reports, bulletins, circulars, and press bulletins aggregating 24,687 pages. These were distributed to 875,056 addresses on regular mailing lists in addition to the number sent in response to special requests. During the past few years the stations have revised their mailing lists, reducing to some extent the total number of names but making the distribution more effective.

The statistics of the stations by States are given in the tables following.

General statistics, 1923

Station	Location	Director	Date of original organization	Date of organization under Hatch Act	Number on staff	Number of teachers on staff	Number of persons on staff who assist in extension work	Publications during fiscal year 1922–23: Number	Publications during fiscal year 1922–23: Pages	Number of names on mailing list
Alabama (College)	Auburn	D. T. Gray	Feb. —, 1883	Feb. 24, 1888	24	11	5	4	122	1,700
Alabama (Canebrake)	Uniontown	W. A. Cammack	Jan. 1, 1886	Apr. 1, 1888						
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		4	3				
Alaska	Sitka	C. C. Georgeson			8			1	58	
Arizona	Tucson	J. J. Thornber		—, 1889	26	21	4	12	290	5,000
Arkansas	Fayetteville	Bradford Knapp		—, 1887	27	20	1	7	298	12,718
California	Berkeley	C. M. Haring	—, 1875	Mar. —, 1888	146	103	82	53	2,446	40,073
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	41	21	10	10	290	2,900
Connecticut (State)	New Haven	W. L. Slate, jr	Oct. 1, 1875	May 18, 1887	24	1		12	582	9,912
Connecticut (Storrs)	Storrs	do		do	12	6		7	235	8,500
Delaware	Newark	C. A. McCue		Feb. 21, 1888	15	10	3	4	134	7,500
Florida	Gainesville	Wilmon Newell		—, 1888	16	1	1	10	213	25,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	7			32	35	6,500
Guam	Guam	C. W. Edwards			4			4	113	
Hawaii	Honolulu	J. M. Westgate			7			1	24	
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	36	20	8	8	152	15,321
Illinois	Urbana	H. W. Mumford		Mar. 21, 1888	111	70	30	24	412	20,000
Indiana	Lafayette	G. I. Christie	—, 1885	Jan. —, 1888	75	20		21	138	35,423
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	82	24	1	37	1,221	30,022
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	85	40		11	416	12,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	60	23	7	8	440	10,000
Louisiana (Sugar)	New Orleans	W. R. Dodson	do							
Louisiana (State)	Baton Rouge	do	Apr. —, 1886		23	2	9	1	20	8,000
Louisiana (North)	Calhoun	do	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	15			10	251	19,951
Maryland	College Park	H. J. Patterson	—, 1888	Apr. —, 1888	28	14		7	105	16,000
Massachusetts	Amherst [1]	S. B. Haskell	—, 1882	Mar. 2, 1888	51	19		29	430	16,000
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	71	29	16	21	551	42,000
Minnesota	University Farm, St. Paul.	W. C. Coffey	Mar. 7, 1885	—, 1888	115	96	84	19	936	13,000
Mississippi	Agricultural College	J. E. Ricks		Jan. 27, 1888	36	13	1	15	304	16,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	57	51		75	1,218	5,834
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		5					
Montana	Bozeman	F. B. Linfield		July 1, 1893	40	19	6	23	480	6,000
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	41	17		19	606	9,390
Nevada	Reno	S. B. Doten		Dec. —, 1887	8	2		4	92	4,270
New Hampshire	Durham	J. C. Kendall	—, 1886	Aug. 4, 1887	23	19	17	10	273	6,568
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		57	21	22	69	1,996	12,321
New Jersey (College)	New Brunswick	do		Apr. 26, 1888	22					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	20	14	2	28	245	10,000
New York (State)	Geneva	R. W. Thatcher	Mar. —, 1882		44			23	434	22,875
New York (Cornell)	Ithaca	A. R. Mann	—— —, 1879	Apr. —, 1888	75	75	12	21	1,624	3,000
North Carolina	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	45	3	2	6	132	33,710
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	38	11		5	304	8,500
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	63			118	2,938	71,590
Oklahoma	Stillwater	C. T. Dowell		Dec. 25, 1890	23	20		11	135	17,825
Oregon	Corvallis	J. T. Jardine		July —, 1888	53	30		29	478	1,456
Pennsylvania	State College	R. L. Watts		June 30, 1887	71	71	50	7	164	44,000
Pennsylvania (Nutrition)	do	E. B. Forbes	—— —, 1907		7					
Porto Rico	Mayaguez	D. W. May			9			3	55	
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	15	2		6	161	2,000
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	28	10	7	5	147	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	18	16		5	144	20,000
Tennessee	Knoxville	H. A. Morgan	June 8, 1882	Aug. 4, 1887	26	1		8	188	12,222
Texas	College Station	B. Youngblood		Apr. 3, 1889	55	1		18	1,102	72,000
Utah	Logan	William Peterson		—— —, 1890	34	31	18	13	204	7,200
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	13	8	2	6	208	6,150
Virginia	Blacksburg	A. W. Drinkard, jr	—— —, 1888	—— —, 1891	32	11	3	5	73	12,000
Virgin Islands	St. Croix	J. B. Thompson			2			2	55	
Washington	Pullman	E. C. Johnson		—— —, 1891	41	11		10	331	11,550
West Virginia	Morgantown	H. G. Knight		June 11, 1888	31	26	3	5	100	26,000
Wisconsin	Madison	H. L. Russell	—— —, 1883	—— —, 1887	98	75	55	11	412	62,076
Wyoming	Laramie	A. D. Faville		Mar. 1, 1891	16	9	1	7	172	8,000
Total					2,259	1,121	462	920	24,687	875,057

[1] In 1882 the State organized a station here and maintained it until June 18, 1895, when it was combined with the Hatch Station at the same place.

Revenue and additions

Station	Revenue						
	Federal		State	Balances [1] from previous year	Fees	Sales	Miscellaneous
	Hatch fund	Adams fund					
Alabama	$15,000.00	$15,000.00	$34,500.00	$7,613.01		$3,732.07	$2,035.00
Alaska							[2] 75,000.00
Arizona	15,000.00	15,000.00	88,171.45	695.87		1,699.33	
Arkansas	15,000.00	15,000.00	56,907.64			20,000.00	
California	15,000.00	15,000.00	558,996.60	1,762.98	$11,024.44	99,342.71	25,872.34
Colorado	15,000.00	15,000.00	125,372.79	15,522.14	12,000.00		
Connecticut (State)	7,500.00	7,500.00	62,537.63	6,928.31	12,000.00		8,526.08
Connecticut (Storrs)	7,500.00	7,500.00	19,500.00	2,676.54			16,261.12
Delaware	15,000.00	15,000.00	20,000.00			10,336.09	
Florida	15,000.00	15,000.00	55,000.00	23,871.24		6,023.79	
Georgia	15,000.00	15,000.00	6,813.35	1,497.25		14,588.34	
Guam							[2] 15,000.00
Hawaii							[2] 50,000.00
Idaho	15,000.00	15,000.00	17,458.48	1,210.10		6,859.09	
Illinois	15,000.00	15,000.00	334,666.68	15,578.81		41,319.33	
Indiana	15,000.00	15,000.00	238,991.38	96,711.10	139,354.87	118,420.88	
Iowa	15,000.00	15,000.00	250,000.00	52,294.89		40,869.59	16.66
Kansas	15,000.00	15,000.00	94,636.35	8,770.96		33,792.38	
Kentucky	15,000.00	15,000.00	50,000.00	19,642.84	49,202.48	35,681.57	5,000.00
Louisiana	15,000.00	15,000.00	56,637.45		25,889.84		
Maine	15,000.00	15,000.00	23,908.25		11,891.96	1,645.59	
Maryland	15,000.00	15,000.00	61,570.32	1,177.36		9,844.57	
Massachusetts	15,000.00	15,000.00	107,410.38		37,522.41	3,983.10	424.39
Michigan	15,000.00	15,000.00	180,000.00	103,376.23		7,063.50	5,314.89
Minnesota	15,000.00	15,000.00	356,746.48			43,057.98	
Mississippi	15,000.00	15,000.00	82,600.00	14,212.43	275.00	23,073.89	293.22
Missouri	15,000.00	15,000.00	36,024.38	7,193.33	25,285.92	19,952.34	
Montana	15,000.00	15,000.00	134,485.55	5,829.49		18,263.57	61.05
Nebraska	15,000.00	15,000.00	178,780.24				
Nevada	15,000.00	15,000.00	1,200.10	592.31		995.00	
New Hampshire	15,000.00	15,000.00	7,000.00	1,553.96		768.85	13,958.89
New Jersey (College)	15,000.00	15,000.00					
New Jersey (State)			155,817.51		49,060.36	31,796.39	
New Mexico	15,000.00	15,000.00	7,500.00	23,258.47		5,575.48	
New York (Cornell)	13,500.00	13,500.00	404,719.12			37,189.15	312.55
New York (State) [3]	1,500.00	1,500.00	211,950.55	5,379.58			
North Carolina	15,000.00	15,000.00	188,346.00			3,298.65	3,800.00
North Dakota	15,000.00	15,000.00	9,592.63	175,691.34		70,198.74	7,750.00
Ohio	15,000.00	15,000.00	252,015.00	70,157.95		35,367.98	1,068.65
Oklahoma [3]	15,000.00	15,000.00	10,500.00			8,073.54	
Oregon	15,000.00	15,000.00	92,000.00	51,214.63		26,474.95	4,000.00
Pennsylvania	15,000.00	15,000.00	27,584.09	2,668.74	469.72	18,365.52	5,237.04
Porto Rico							[2] 50,000.00
Rhode Island	15,000.00	15,000.00	10,325.53	2,551.17		5,582.73	
South Carolina	15,000.00	15,000.00	64,849.18	1,417.51		24,754.41	
South Dakota	15,000.00	15,000.00	14,420.00	7,036.00		1,512.04	6,193.81
Tennessee	15,000.00	15,000.00	53,973.32			500.52	
Texas	15,000.00	15,000.00	197,985.00	4,410.24		72,722.99	
Utah	15,000.00	15,000.00	49,662.90			6,987.85	
Vermont	15,000.00	15,000.00				344.93	
Virginia	15,000.00	15,000.00	57,860.39	14,548.70		10,867.30	693.10
Virgin Islands							[2] 20,000.00
Washington	15,000.00	15,000.00	105,276.61	11,076.30		49,893.76	
West Virginia	15,000.00	15,000.00	120,000.00	4,203.11		35,084.83	
Wisconsin	15,000.00	15,000.00	252,783.69			42,948.31	5,596.33
Wyoming	15,000.00	15,000.00	12,000.00	5,620.62		1,384.92	
Total	720,000.00	720,000.00	5,539,077.02	767,945.51	373,977.00	1,050,238.55	322,415.12

[1] Not including balances from Federal funds.
[2] Supported by direct appropriation to the United States Department of Agriculture.

to equipment, 1923

Revenue	Additions to equipment						
Total	Buildings	Library	Apparatus	Farm implements	Livestock	Miscellaneous	Total
$77,880.08	$3,170.63	$508.93	$1,532.77	$1,408.12	$1,439.60	$510.61	$8,570.66
75,000.00							
120,566.65	2,530.52		1,114.89	4,084.44	720.88	659.07	9,109.80
106,907.64			500.00	600.00	1,000.00	350.00	2,450.00
726,999.07	119,993.43	3,647.25	7,755.89	13,773.33	4,963.93	10,586.49	160,720.32
182,894.93	5,566.00	616.00	4,866.00	1,599.37	7,238.00	22,358.00	42,243.37
104,992.02	80.02	891.82	1,379.23	1,004.38		2,947.08	6,302.53
53,437.66	1,000.00	100.00	500.00	200.00			1,800.00
60,336.09		334.65	1,010.76	571.81	1,500.00	465.85	3,883.07
114,895.03	14,862.67	997.11	1,223.81	451.67	1,205.40	1,459.31	20,199.97
52,898.94	6,055.62	451.56	1,193.31	1,286.51	784.74		9,771.74
15,000.00							
50,000.00							
55,527.67	900.00	60.00	980.00	550.00	2,000.00	350.00	4,840.00
421,564.82	288,769.62					29,183.80	317,953.42
623,478.23	14,586.47	852.91	550.81	4,395.22	6,050.22	1,560.17	27,995.80
373,181.14			4,825.40	1,513.79	237.50		6,576.69
167,199.69	8,000.00	70.05	259.41	8,853.67	5,180.73	1,247.17	23,611.03
189,526.89		965.58	703.67	1,187.28	1,921.00	493.25	5,270.78
112,527.29	2,576.38	140.49	673.23	2,464.61	1,223.42	307.00	7,385.13
67,445.80		686.27	48.96	1,172.32		87.63	1,995.18
102,592.25	2,358.70	356.69	1,701.11	1,869.63	200.00	818.20	7,304.33
179,340.28	2,328.93	1,193.57	761.27	2,224.75	21.45	419.40	6,949.37
325,754.62	11,000.00	500.00	2,000.00	1,000.00	200.00		14,700.00
429,804.46	19,971.84	1,330.86	1,696.89	6,197.67	8,866.51	3,258.97	41,322.74
150,454.54	5,115.00	37.47	1,153.34	717.65	829.50	2,154.32	10,007.28
118,455.97	982.33	121.33	1,989.64	851.17	2,033.10	619.52	6,597.09
188,639.66	12,483.00	97.54	1,142.00	7,582.00	1,033.00	2,241.00	24,578.54
208,780.24	30,000.00	2,489.00		7,129.06	17,142.58	21,126.88	77,887.52
32,787.41	689.72	588.12	158.53	49.75	781.30	374.00	2,641.42
53,281.70	508.58	294.55	766.99	306.25		67.73	1,944.10
30,000.00	4,934.61	1,037.00	26,096.90	3,293.39	1,674.06	5,030.23	42,066.19
236,674.26							
66,333.95	1,407.72	127.74	413.43	1,146.62	1,009.17	496.60	4,601.28
469,220.82	204,255.35	915.96	10,172.15	1,610.83	509.25	1,452.66	218,916.20
220,330.13	3,500.00	1,200.00	3,600.00	1,700.00			10,000.00
225,444.65	18,931.18		241.95	4,442.10	1,175.80	589.49	25,380.52
293,232.71	10,000.00	137.97	280.28	7,412.91	9,875.35		27,706.51
388,609.58	16,472.84	682.73	767.42	847.53	4,815.15	5,032.01	28,617.68
48,573.54	4,000.00	1,244.66	678.23	322.56	264.10		6,509.55
203,689.58	4,345.07	116.11	60.00	1,039.46	9,284.84	4,644.06	19,489.54
84,325.11	25,000.00	693.14	4,261.27	2,472.67	3,078.11		35,505.19
50,000.00							
48,459.43	94.75	349.35	414.83	367.04	56.25	710.37	1,992.59
121,021.10	2,200.00	900.00	150.00	500.00	800.00	750.00	5,300.00
59,161.85		20.00	409.00	240.00	300.00		969.00
84,473.84	500.00	215.25	134.92	1,715.29	3,985.00	70.00	6,620.46
305,118.23	9,181.40	981.60	3,215.36	13,877.05	3,450.25	9,757.72	40,463.38
86,650.75		300.00	1,800.00	500.00		300.00	2,900.00
30,344.93		192.53	1,426.38	50.46	461.50		2,130.87
113,969.49	13,775.94	493.66	738.95	1,767.67	1,095.00	6,300.00	24,171.22
20,000.00							
196,246.67	5,281.99	545.59	298.40	3,892.12	685.30	666.34	11,369.74
189,287.94	21,471.22	428.28	216.77	3,884.28	3,088.85	954.63	30,044.03
331,328.33	9,285.67	1,393.18	4,844.86	5,943.28	5,696.76	4,920.73	32,084.48
49,005.54	19,925.62	1,075.00	316.74	838.64	3,111.25	2,845.32	28,112.57
9,493,653.20	928,092.82	30,381.50	101,025.75	130,908.35	120,988.85	148,165.61	1,459,562.88

[5] Including balances: New York (State), $0.41; Hatch; Oklahoma, $415.93 Hatch, $1,746.07 Adams.

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$9,294.68	$1,228.15	$513.20	$370.00	$106.40	--------	$187.67
Arizona	15,000.00	7,982.13	948.48	33.75	541.83	414.96	$86.03	559.72
Arkansas	15,000.00	8,265.00	1,567.93	1,018.67	377.07	413.25	287.36	116.48
California	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Colorado	15,000.00	12,112.46	401.28	190.75	29.26	13.55	--------	87.81
Connecticut (State)	7,500.00	7,500.00	--------	--------	--------	--------	--------	--------
Connecticut (Storrs)	7,500.00	7,500.00	--------	--------	--------	--------	--------	--------
Delaware	15,000.00	10,269.33	891.71	1,178.46	525.91	44.51	430.38	136.71
Florida	15,000.00	11,373.66	991.34	28.00	84.16	19.77	21.05	237.40
Georgia	15,000.00	8,476.63	3,159.59	33.00	479.83	182.90	688.87	--------
Idaho	15,000.00	11,473.98	1,972.53	190.26	28.92	51.50	49.50	281.50
Illinois	15,000.00	14,962.53	--------	--------	32.81	--------	--------	--------
Indiana	15,000.00	14,500.00	358.00	--------	17.87	--------	--------	--------
Iowa	15,000.00	8,415.00	752.92	462.96	259.54	--------	189.17	149.87
Kansas	15,000.00	9,450.00	4,365.25	6.26	213.22	--------	--------	149.97
Kentucky	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Louisiana	15,000.00	9,122.73	3,774.21	95.00	106.02	22.39	606.04	.50
Maine	15,000.00	6,402.51	3,520.68	90.94	400.80	267.69	853.54	6.54
Maryland	15,000.00	14,152.62	68.12	--------	8.91	161.70	--------	327.02
Massachusetts	15,000.00	12,980.00	1,442.13	--------	--------	--------	--------	1.31
Michigan	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Minnesota	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Mississippi	15,000.00	9,578.34	2,741.52	--------	12.70	54.19	203.36	--------
Missouri	15,000.00	10,389.04	1,766.91	--------	105.97	136.11	44.44	169.11
Montana	15,000.00	14,655.00	2.00	224.72	118.28	--------	--------	--------
Nebraska	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Nevada	15,000.00	9,350.52	1,919.62	445.24	167.17	17.67	75.80	--------
New Hampshire	15,000.00	10,251.00	644.75	1,198.50	209.66	263.67	600.00	198.10
New Jersey	15,000.00	10,282.16	823.23	630.32	188.27	3.62	455.34	454.06
New Mexico	15,000.00	5,793.13	3,561.23	1,450.83	172.64	171.04	233.79	65.06
New York (State)[1]	1,500.00	424.94	1,075.06	--------	--------	--------	--------	--------
New York (Cornell)	13,500.00	8,875.00	1,986.14	--------	16.25	12.00	114.13	1,137.00
North Carolina	15,000.00	9,738.04	1,891.17	--------	118.73	59.65	86.30	228.13
North Dakota	15,000.00	15,000.00	--------	--------	--------	--------	--------	--------
Ohio	15,000.00	13,075.29	648.29	--------	133.00	9.76	690.00	31.21
Oklahoma	15,000.00	6,627.23	1,980.83	1,244.88	227.43	272.08	71.69	431.81
Oregon	15,000.00	11,599.00	2,746.14	208.85	22.63	37.67	21.15	80.24
Pennsylvania	15,000.00	11,800.00	311.81	1,819.05	28.68	84.80	6.48	26.75
Rhode Island	15,000.00	5,129.53	4,708.30	1,326.25	231.62	258.79	343.87	1.80
South Carolina	15,000.00	8,638.32	1,394.17	88.85	419.13	362.07	12.00	28.83
South Dakota	15,000.00	8,261.58	1,463.54	3,202.20	34.00	77.98	--------	382.20
Tennessee	15,000.00	11,395.12	904.25	202.31	332.77	118.60	757.20	145.90
Texas	15,000.00	14,141.05	--------	--------	39.76	--------	--------	--------
Utah	15,000.00	12,120.67	1,275.47	--------	17.16	50.86	--------	30.66
Vermont	15,000.00	8,131.02	1,663.74	1,605.40	279.68	30.42	810.75	113.43
Virginia	15,000.00	10,195.97	3,099.69	--------	156.63	112.42	23.01	36.21
Washington	15,000.00	9,227.16	2,518.10	1,232.30	10.13	--------	--------	.93
West Virginia	15,000.00	9,000.00	1,570.39	26.42	--------	57.64	--------	104.34
Wisconsin	15,000.00	10,564.66	2,151.25	122.51	--------	--------	--------	919.92
Wyoming	15,000.00	10,610.00	1,225.33	165.47	--------	--------	148.35	195.34
Total	720,000.00	524,087.03	69,515.25	19,035.35	6,518.44	3,889.66	7,909.60	7,023.53

[1] Including a balance of $0.41.

ct of March 2, 1887 (Hatch Act) for the year ended June 30, 1923

Classified expenditures											
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
$342.58	$357.89	$554.87	$346.42	$202.93	$234.03	$346.46	$669.10	$133.80	$5.20	$107.52	--------
359.41	37.70	2,198.47	--------	460.08	70.60	658.50	162.00	455.79	10.00	20.55	--------
1,253.01	116.14	625.29	15.00	320.59	2.52	11.37	141.38	423.04	--------	45.90	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
275.25	--------	254.93	71.35	--------	53.50	325.82	28.00	451.33	--------	704.71	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
335.28	12.90	--------	323.84	59.72	340.19	4.80	--------	323.22	17.50	105.54	--------
197.27	349.93	499.95	243.24	92.45	175.11	31.32	--------	363.00	.58	291.76	$0.01
430.40	477.80	150.88	338.24	388.69	19.64	7.48	2.25	149.80	--------	14.00	--------
212.39	90.00	56.20	--------	53.42	--------	65.18	--------	359.52	--------	115.10	--------
--------	--------	--------	--------	4.66	--------	--------	--------	--------	--------	--------	--------
4.53	1.63	--------	--------	--------	--------	--------	--------	117.97	--------	--------	--------
427.38	--------	4,147.26	--------	39.04	2.80	1.21	--------	143.71	--------	9.14	--------
192.31	--------	--------	--------	208.39	30.00	59.09	--------	307.51	--------	18.00	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
247.51	--------	381.25	27.00	54.30	14.50	--------	--------	395.11	--------	153.44	--------
496.76	179.46	1,467.35	565.09	16.47	120.77	10.67	--------	406.77	--------	193.96	--------
22.67	--------	--------	--------	1.43	21.80	232.55	--------	3.18	--------	--------	--------
167.34	321.97	--------	--------	52.25	--------	--------	35.00	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
826.92	124.88	1,248.00	--------	163.73	--------	--------	--------	--------	--------	46.36	--------
590.35	82.33	1,187.32	17.00	95.75	5.12	141.87	78.30	131.50	--------	58.88	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
340.55	--------	120.52	514.23	254.83	203.21	2.18	30.00	995.46	--------	563.00	--------
204.26	149.02	--------	294.55	101.91	56.43	187.50	--------	639.61	--------	1.04	--------
396.44	--------	300.00	4.00	45.75	30.87	16.00	--------	1,259.11	3.50	107.33	--------
486.06	202.42	597.02	30.30	564.33	154.55	8.89	573.72	458.74	--------	476.25	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
401.21	33.50	--------	40.48	245.39	253.30	157.15	--------	--------	--------	228.45	--------
174.27	658.42	699.16	--------	--------	--------	--------	440.00	156.13	--------	750.00	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
124.30	288.15	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
480.89	11.39	1,159.28	744.66	294.91	34.00	379.24	114.30	446.45	--------	63.00	415.93
116.96	--------	--------	--------	--------	--------	25.76	--------	141.60	--------	--------	--------
489.22	88.86	6.25	--------	48.67	11.69	12.96	--------	202.51	--------	62.27	--------
424.08	1,016.47	349.49	433.42	260.59	30.24	13.05	--------	231.06	--------	241.44	--------
330.98	401.94	705.03	824.94	214.59	750.92	1.29	10.60	151.21	--------	665.13	--------
277.19	--------	421.86	--------	203.00	110.00	198.35	--------	139.62	--------	228.48	--------
145.76	30.25	--------	264.31	136.94	74.64	42.61	--------	244.98	--------	204.36	--------
--------	--------	--------	--------	161.09	242.00	--------	--------	--------	--------	416.10	--------
403.32	--------	97.23	22.40	31.75	17.27	--------	180.00	753.21	--------	--------	--------
1,055.55	84.91	--------	159.19	86.46	--------	19.14	--------	486.39	--------	473.92	--------
511.28	320.69	2.98	160.55	192.72	45.84	35.06	--------	9.20	--------	97.75	--------
354.59	68.76	--------	--------	134.40	50.05	8.01	--------	1,395.57	--------	--------	--------
1,372.69	86.45	--------	--------	872.09	404.58	626.39	--------	879.01	--------	--------	--------
378.06	33.43	--------	--------	--------	--------	718.58	--------	111.59	--------	--------	--------
120.25	54.00	1,954.37	--------	328.90	59.15	27.30	--------	44.00	48.00	19.54	--------
14,969.27	5,681.29	19,184.96	5,440.21	6,391.32	3,619.32	4,375.78	2,464.65	12,910.70	84.78	6,482.92	415.94

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000.00	$10,966.66	$830.94	$27.70	$77.65		$768.01	$262.43
Arizona	15,000.00	12,397.87	347.40	191.59	86.99		165.73	76.62
Arkansas	15,000.00	9,465.00	2,861.47	129.30	114.49	$236.60	507.63	383.20
California	15,000.00	11,615.00	872.04	67.93		159.01	450.03	570.52
Colorado	15,000.00	13,232.96	62.35	2.95	18.33		703.18	53.28
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	11,845.65	494.33	15.10	61.37		1,005.71	265.49
Florida	15,000.00	13,750.00	168.14	20.38	46.22	7.80	282.38	54.14
Georgia	15,000.00	10,920.00	152.98		210.99	504.64	884.69	21.69
Idaho	15,000.00	11,320.58	1,609.17	17.55	300.44	212.50	321.61	109.45
Illinois	15,000.00	13,332.47	1,574.98					
Indiana	15,000.00	11,460.00	375.79	99.01			646.63	719.37
Iowa	15,000.00	9,395.00	2,772.38	112.89		110.85	821.79	442.01
Kansas	15,000.00	10,550.00	2,885.60	2.25	8.80	.50	96.38	119.33
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	13,374.94	765.00	23.87	25.53	260.10	160.82	115.14
Maine	15,000.00	14,716.56		52.00	2.14			69.73
Maryland	15,000.00	13,261.72	12.09	27.00		196.17	406.93	42.59
Massachusetts	15,000.00	14,631.00	310.31				21.92	5.95
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	10,563.52	1,456.36	4.43	118.80	105.16	1,321.33	581.49
Missouri	15,000.00	6,018.25	1,638.79	28.23	207.77	176.91	864.97	406.95
Montana	15,000.00	10,444.68	2,189.21	3.90	40.34		486.46	238.30
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	8,868.00	3,130.10	10.78	129.40	298.25	325.79	117.84
New Hampshire	15,000.00	11,110.00	1,302.05	6.30	82.37		455.43	174.27
New Jersey	15,000.00	12,200.51	357.23	11.99	4.75	869.66	696.94	62.29
New Mexico	15,000.00	8,986.48	2,524.32	84.61	226.63	161.86	902.26	230.11
New York (State)	1,500.00	1,500.00						
New York (Cornell)	13,500.00	9,875.00	3,608.21	6.10			8.04	
North Carolina	15,000.00	13,433.29	1,055.06	119.76	15.78	94.30	25.95	
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	14,047.92	769.72				31.76	54.60
Oklahoma	15,000.00	11,299.63	1,018.62				440.76	97.38
Oregon	15,000.00	12,960.35	379.56	2.21	116.03	32.29	962.69	136.49
Pennsylvania	15,000.00	10,679.00	235.76	5.37	84.56	5.80	796.90	75.41
Rhode Island	15,000.00	9,349.50	3,063.95	29.39	19.51	725.82	91.32	56.55
South Carolina	15,000.00	10,448.22	2,096.94	46.33	25.27	229.44	201.56	200.28
South Dakota	15,000.00	8,988.24	4,119.79	106.65	12 47		282.11	448.21
Tennessee	15,000.00	13,450.00	197.45	29.55	58.79	234.22	451.60	58.86
Texas	15,000.00	14,182.05	420.00			16.50	125.16	170.59
Utah	15,000.00	9,596.07	3,668.23	54.25	31.95		479.45	193.73
Vermont	15,000.00	8,473.32	3,019.47	80.70	6.44	62.17	202 07	251.58
Virginia	15,000.00	9,449.88	3,157.03	1.25	100.19	20.06	176.83	375.73
Washington	15,000.00	12,602.90	1,068.06	.82		58.32	375.54	188.19
West Virginia	15,000.00	10,600.00	629.43	28.52			271.17	727.11
Wisconsin	15,000.00	10,209.88	3,453.80		3.22		266.44	131.89
Wyoming	15,000.00	12,856.07	335.65	5.55	28.13		234.36	30.34
Total	720,000.00	568,428.22	61,089.79	1,456.21	2,265.35	4,778.93	17,720.33	8,319.13

act of March 16, 1906 (Adams Act) for the year ended June 30, 1923

Classified expenditures										
Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
-	$139.10	$123.41	$141.89	$8.50	$949.13	$244.00	$125.90	-	$334.68	-
-	-	-	405.89	54.25	456.39	-	805.27	-	12.00	-
103.30	275.85	-	501.98	54.05	66.42	23.15	257.11	-	20.45	-
-	186.35	25.85	279.26	60.95	199.16	217.68	189.57	-	106.65	-
-	33.27	8.00	-	8.50	681.38	-	195.80	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
39.00	-	10.81	102.24	55.00	826.85	-	278.45	-	-	-
215.00	-	2.40	28.21	17.80	57.90	-	318.75	-	30.88	-
100.00	1,085.19	70.67	30.84	-	247.40	604.74	166.17	-	-	-
-	128.75	-	231.45	-	19.38	-	652.82	-	76.30	-
-	45.10	-	-	-	12.45	35.00	-	-	-	-
13.90	29.86	-	207.70	8.59	293.85	969.65	175.65	-	-	-
-	588.66	-	334.40	-	-	-	275.77	-	146.25	-
-	352.97	-	301.78	25.45	6.16	472.85	175.27	-	2.66	-
-	-	-	-	-	-	-	-	-	-	-
-	163.60	70.89	-	-	3.15	-	36.96	-	-	-
-	-	-	-	-	-	-	159.57	-	-	-
-	-	5.40	161.81	5.90	740.07	-	120.25	-	20.07	-
-	-	-	-	20.25	10.57	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	-	44.31	394.37	1.20	142.37	-	266.66	-	-	-
13.24	3,799.73	-	127.47	12.01	1,185.73	175.05	-	-	344.90	-
-	-	58.66	255.37	11.53	864.30	-	407.25	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	740.88	27.00	41.35	-	43.46	794.15	423.00	-	-	-
-	551.58	-	204.34	11.30	579.49	-	15.33	-	507.54	-
-	60.00	9.00	47.75	29.26	402.18	-	40.55	$60.75	147.14	-
248.32	263.80	18.35	416.58	142.17	361.83	70.00	22.52	-	340.16	-
-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	2.62	-	-	-	-	-
140.98	-	-	-	-	26.91	-	87.97	-	-	-
-	-	-	-	-	-	-	-	-	-	-
-	6.00	-	-	-	90.00	-	-	-	-	-
52.50	18.35	-	27.65	-	298.99	-	-	-	-	$1,746.07
-	4.20	28.07	226.00	-	102.45	-	48.90	.76	-	-
2.50	103.28	156.43	11.67	27.88	2,380.30	19.35	104.65	-	261.14	-
-	1,121.68	45.20	45.55	-	10.00	10.00	5.05	-	426.48	-
200.00	15.00	2.06	308.73	600.00	626.17	-	-	-	-	-
30.00	128.40	26.49	49.07	154.55	292.12	4.00	302.06	-	55.84	-
1.30	-	31.49	118.73	26.60	96.50	-	220.91	-	24.00	-
-	-	-	-	-	40.00	-	45.70	-	-	-
-	-	25.50	47.61	111.36	393.79	-	306.85	-	91.21	-
-	170.88	1.34	21.00	-	1,323.65	461.50	175.88	-	750.00	-
310.00	495.63	-	101.68	-	533.80	-	92.76	-	185.16	-
-	263.51	-	20.00	-	223.21	49.00	150.45	-	-	-
-	74.17	6.00	275.06	51.00	1,426.80	-	910.74	-	-	-
-	822.85	-	4.50	-	71.42	36.00	-	-	-	-
-	915.18	-	29.80	237.17	-	70.25	217.63	-	39.87	-
1,470.04	12,583.82	797.33	5,501.73	1,735.27	16,088.35	4,256.37	7,778.17	61.51	3,923.38	1,746.07

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906

State or Territory	Hatch Act		Adams Act	
	1888–1922	1923	1906–1922	1923
Alabama	$523,956.42	$15,000.00	$221,619.89	$15,000.00
Arizona	489,803.10	15,000.00	224,955.61	15,000.00
Arkansas	523,139.12	15,000.00	224,900.00	15,000.00
California	525,000.00	15,000.00	224,926.84	15,000.00
Colorado	524,718.82	15,000.00	223,638.93	15,000.00
Connecticut	525,000.00	15,000.00	225,000.00	15,000.00
Dakota Territory	56,250.00			
Delaware	523,382.87	15,000.00	220,475.12	15,000.00
Florida	524,966.06	15,000.00	224,996.06	15,000.00
Georgia	520,593.43	15,000.00	212,092.87	15,000.00
Idaho	449,324.13	15,000.00	220,842.22	15,000.00
Illinois	524,564.95	15,000.00	224,851.62	15,000.00
Indiana	524,901.19	15,000.00	225,000.00	15,000.00
Iowa	525,000.00	15,000.00	225,000.00	15,000.00
Kansas	524,995.00	15,000.00	225,000.00	15,000.00
Kentucky	524,996.57	15,000.00	225,000.00	15,000.00
Louisiana	525,000.00	15,000.00	225,000.00	15,000.00
Maine	524,999.62	15,000.00	225,000.00	15,000.00
Maryland	524,967.40	15,000.00	224,236.48	15,000.00
Massachusetts	524,617.70	15,000.00	225,000.00	15,000.00
Michigan	524,676.10	15,000.00	221,341.20	15,000.00
Minnesota	524,917.78	15,000.00	224,345.00	15,000.00
Mississippi	525,000.00	15,000.00	225,000.00	15,000.00
Missouri	520,097.24	15,000.00	224,999.90	15,000.00
Montana	435,000.00	15,000.00	222,417.04	15,000.00
Nebraska	524,932.16	15,000.00	225,000.00	15,000.00
Nevada	524,214.32	15,000.00	223,180.28	15,000.00
New Hampshire	525,000.00	15,000.00	225,000.00	15,000.00
New Jersey	524,949.97	15,000.00	224,392.06	15,000.00
New Mexico	489,509.05	15,000.00	225,000.00	15,000.00
New York	524,757.59	14,999.59	224,463.01	15,000.00
North Carolina	525,000.00	15,000.00	210,000.00	15,000.00
North Dakota	466,502.26	15,000.00	224,638.85	15,000.00
Ohio	525,000.00	15,000.00	223,514.02	15,000.00
Oklahoma	449,568.96	14,584.07	206,360.56	13,253.93
Oregon	510,156.64	15,000.00	220,000.00	15,000.00
Pennsylvania	524,967.43	15,000.00	224,995.41	15,000.00
Rhode Island	525,000.00	15,000.00	222,464.20	15,000.00
South Carolina	524,542.15	15,000.00	223,460.12	15,000.00
South Dakota	468,250.00	15,000.00	220,000.00	15,000.00
Tennessee	525,000.00	15,000.00	225,000.00	15,000.00
Texas	525,000.00	15,000.00	222,592.26	15,000.00
Utah	390,000.00	15,000.00	224,821.94	15,000.00
Vermont	525,000.00	15,000.00	225,000.00	15,000.00
Virginia	522,824.12	15,000.00	224,949.01	15,000.00
Washington	462,102.65	15,000.00	221,080.11	15,000.00
West Virginia	524,968.71	15,000.00	222,859.12	15,000.00
Wisconsin	525,000.00	15,000.00	225,000.00	15,000.00
Wyoming	510,000.00	15,000.00	225,000.00	15,000.00
Total	24,582,113.51	719,583.66	10,704,409.73	718,253.93

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UNITED STATES DEPARTMENT OF AGRICULTURE

OFFICE OF EXPERIMENT STATIONS

Washington, D. C. February, 1926

WORK AND EXPENDITURES OF THE AGRICULTURAL EXPERIMENT STATIONS, 1924

By E. W. Allen, W. H. Beal, and E. R. Flint

CONTENTS

In accordance with acts of Congress giving the Department of Agriculture administrative, supervisory, and advisory functions with regard to the Federal funds for the maintenance of agricultural experiment stations in the United States and its outlying possessions, the Office of Experiment Stations to which these functions are assigned, submits herewith a report on the work and expenditures of these stations for the fiscal year ended June 30, 1924.

The reorganization of the Department of Agriculture which became effective July 1, 1923, involved the dissolution of the States Relations Service, of which the Office of Experiment Stations had been a division since July 1, 1915, and resulted in the establishment of the office as a separate unit but did not alter its relations with the experiment stations or materially modify its functions. These include (1) personal examination by representatives of the office of the work and expenditures of the stations each year, (2) review and advice regarding new projects and programs of work or revisions of old projects, (3) advice regarding questions of personnel, policy, and administration, (4) review of the literature of agricultural research throughout the world in Experiment Station Record and the preparation of other bibliographical aids to agricultural research, and (5) direct supervision of the work of the experiment stations maintained by the Department of Agriculture in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands.

FUNDS FOR STATION USE

The Federal funds for station use subject to administrative oversight by the office amounted to $1,743,600 during the year ended June 30, 1924. Of this, $1,440,000 was for the State experiment stations under the provisions of the Hatch and Adams Acts, and $205,000 for the support of the experiment stations in Alaska and the insular possessions. The total fund available for station use exclusive of

the Federal funds was $8,594,074, of which $6,115,027 was from State appropriations and $2,479,047 was from fees, sales, balances from the previous year, and miscellaneous sources, as shown in the following table:

Resources of the agricultural experiment stations from within the States for the year ended June 30, 1924

States	State appropriations	Balances	Fees	Sales	Miscellaneous	Total
Alabama	$34, 500. 00	$6, 054. 58		$16, 696. 57		$57, 251. 15
Arizona	93, 305. 06	1, 287. 88		1, 613. 54		96, 206. 48
Arkansas	50, 703. 37			15, 676. 94		66, 380. 31
California	434, 539. 92	26, 336. 43	$9, 223. 11	102, 622. 81	$16, 662. 87	589, 385. 14
Colorado	117, 540. 92	28, 951. 72		33, 332. 75		179, 825. 39
Connecticut State	88, 858. 34	226. 08	11, 000. 00		8, 048. 73	108, 133. 15
Connecticut Storrs	33, 004. 50	2, 098. 70			15, 085. 24	50, 188. 44
Delaware	17, 500. 00	2, 528. 10		11, 492. 69		31, 520. 79
Florida	91, 000. 00	20, 317. 18		9, 377. 61	8, 690. 26	129, 385. 05
Georgia	8, 000. 00	2, 396. 94		25, 786. 23		36, 183. 17
Idaho	28, 203. 31	209. 41				28, 412. 72
Illinois	368, 158. 87	27, 141. 13		61, 629. 50		456, 929. 50
Indiana	225, 081. 38	108, 103. 02	123, 443. 50	76, 312. 16	21, 072. 72	554, 012. 78
Iowa	250, 000. 00	32, 569. 13		36, 531. 95		319, 101. 08
Kansas	103, 550. 00	12, 527. 60		55, 921. 03		171, 998. 63
Kentucky	68, 000. 00	45, 243. 79	99, 158. 43	41, 144. 40	5, 000. 00	258, 546. 62
Louisiana	40, 000. 00	3, 975. 87	34, 157. 23	7, 264. 00	6, 193. 42	91, 590. 52
Maine	25. 000. 00		11, 886. 07	15, 420. 18		52, 306. 25
Maryland	86, 943. 72			16, 837. 37	11, 409. 25	115, 190. 34
Massachusetts	124, 359. 87		40, 733. 93	9, 710. 88	393. 54	175, 198. 22
Michigan	157, 963. 95			15, 626. 93		173, 590. 88
Minnesota	380, 518. 80			49, 709. 71		430, 228. 51
Mississippi	88, 196. 75	3, 936. 98		7, 394. 68		99, 528. 41
Missouri	67, 108. 55	35, 322. 76	28, 698. 16	57, 618. 41		188, 747. 88
Montana	107. 598. 62			27, 479. 06		135, 077. 68
Nebraska	123, 301. 00	22, 759. 10		40, 899. 12		186, 959. 22
Nevada	783. 65	861. 32		2, 195. 93		3, 840. 90
New Hampshire	7, 000. 00	986. 70		2, 081. 70	14, 724. 91	24, 793. 31
New Jersey	167, 500. 00		52, 029. 42	24, 324. 12		243, 853. 54
New Mexico	7, 500. 00	22, 208. 64		10, 453. 70		40, 162. 34
New York State	247, 451. 12			3, 312. 17		250, 763. 29
New York Cornell	239, 130. 65			34, 398. 47	266. 38	273, 795. 50
North Carolina	149, 161. 99	1, 497. 17		46, 030. 67		196, 689. 83
North Dakota	296, 516. 68	40, 469. 85		65, 995. 02	9, 508. 42	412, 489. 97
Ohio	597, 575. 00	13, 301. 73		55, 875. 23	673. 30	667, 425. 26
Oklahoma	12, 500. 00			6, 679. 26		19, 179. 26
Oregon	99, 500. 00	55, 337. 22			32, 161. 82	186, 999. 04
Pennsylvania	62, 225. 12			18, 636. 43		80, 861. 55
Rhode Island	3, 087. 27	2, 885. 14		7, 578. 88		13, 551. 29
South Carolina	70, 777. 60	1, 928. 71		35, 989. 24		108, 695. 55
South Dakota	35, 420. 00	5, 547. 02		9, 345. 00	3, 132. 18	53, 444. 20
Tennessee	41, 949. 52			13, 633. 69		55, 583. 21
Texas	294, 000. 00	12, 823. 23		78, 124. 43		384, 947. 66
Utah	46, 904. 73	562. 83		9, 322. 41	1, 000. 00	57, 789. 97
Vermont	5, 000. 00	586. 97	9, 741. 93	517. 80		15, 846. 70
Virginia	64, 912. 50	11, 362. 68		8, 732. 08	631. 53	85, 638. 79
Washington	107, 030. 78	17, 268. 72		51, 987. 20		176, 286. 70
West Virginia	90, 000. 00	4, 451. 46		27, 254. 55		121, 706. 01
Wisconsin	243, 663. 66			67, 944. 30	9, 740. 85	321, 348. 81
Wyoming	12, 500. 00	1, 674. 48		2, 329. 09		16, 503. 57
Total	6, 115, 027. 20	575, 740. 27	420, 071. 78	1, 318, 839. 89	164, 395. 42	8, 594, 074. 56
Federal funds						1, 440, 000. 00
Total						10, 034, 074. 56

For the first time every station received some State aid during the fiscal year 1924. There was an increase in total income of over $500,000 as compared with that of the previous year. Four stations reported no changes in their State appropriations, 29 an increase, and 17 a decrease.

Eleven stations received over $200,000 from State appropriations—Ohio, California, Minnesota, Illinois, North Dakota, Texas, Iowa, New York State station, Wisconsin, New York Cornell station, and Indiana. Nine stations receiving between $100,000 and $200,000 were New Jersey, Michigan, North Carolina, Massachusetts, Nebraska, Colorado, Montana, Washington, and Kansas. Thirteen stations receiving between $50,000 and $100,000 were Oregon, Arizona, Florida, West Virginia, Connecticut State station, Mississippi, Maryland, South Carolina, Kentucky, Missouri, Virginia, Pennsylvania, and Arkansas. Eight stations received from $25,000 to $50,-

000—Utah, Tennessee, Louisiana, South Dakota, Alabama, Connecticut Storrs station, Idaho, and Maine. Three stations—Delaware, Oklahoma, and Wyoming—received from $10,000 to $20,000. The remaining six stations—Georgia, New Mexico, New Hampshire, Rhode Island, Vermont, and Nevada—received less than $10,000 each. Further details of the station receipts and expenditures will be found on page 105.

The oversight of the Federal funds for the experiment stations pertains not only to the actual expenditures but equally as much to the maintenance of conditions favorable for the efficient use of the funds, the provision of suitable personnel, and the encouragement of an adequate grade of research effort.

TRENDS OF STATION WORK

A critical study of the progress of the research work of the experiment stations indicates certain marked and significant trends and developments. Among these are (1) sharper differentiation of research, regulatory, and service work, (2) the adoption of more specific and fundamental projects evidencing a deeper scientific insight, and (3) improvement of methods, apparatus, and technique.

About one-third of the stations, principally in the Eastern States, are still charged with regulatory or service duties of various kinds which lie outside of their primary functions as research institutions, but in recent years there has been a relative decrease in the extent and importance of station participation in such work. State departments of agriculture and similar agencies have been encouraged to take over such work and are doing so to an increasing extent. Special effort has been made by the office to obtain more exact information on this point, and with this end in mind a modification of the form of annual financial report required of the stations was put into effect during the year, which provides for a measure of differentiation of the amounts expended for research, maintenance of branch stations, surveys, conduct of farms and related commercial enterprises, and regulatory and service duties. A rough classification, based on the financial reports for the year ended June 30, 1924, shows that of the approximately $10,000,000 available for the use of the stations during that year nearly $6,500,000 was spent strictly for research and experimental purposes. Something over $500,000 was used for regulatory and public service work, and nearly $200,000 for surveys of various kinds.

Appreciation of the need of more fundamental research and of improved methods, technique, and equipment for this purpose was evident, especially in a more critical examination of the scientific competency of field and feeding experiments, the development of experimental work depending upon improved means of controlling or taking accurate account of environmental factors, and in the progress of more advanced forms of investigations in genetics, economics, and engineering.

Genetics.—The progress and importance of research in genetics as a distinct field of research was recognized by assigning to this subject a separate section in Experiment Station Record in which are brought together the more fundamental studies on the subject. Something over 100 distinct projects in genetics were reported as active at the stations during the year. Reviews of station work in genetics will be found on pages 43, 61, 67 of this report.

Economics.—The development of station research in economics has been comparatively recent, but it has made notable advance. Ten years ago there was a relatively insignificant number of station projects and workers in this field. Now the stations report over 200 active projects and more than 100 workers in economics definitely assigned to the station staffs. Despite limited resources, lack of competent investigators, and other difficulties incident to a new and distinctive research enterprise, a considerable amount of creditable and valuable work has been done, much of it through regional and national cooperation. To an increasing extent the methods of scientific research are being effectively applied to the collection and interpretation of economic facts. The opportunity for leadership by the experiment stations in this field is being more fully recognized and emphasized.

Engineering.—Interest in the development of more formal investigation in agricultural engineering is growing. The opportunity in this field is undoubtedly large, but properly trained men and facilities are limited. The office has encouraged and aided this development quite actively in various ways, and in a number of States steps were taken to give more systematic attention to such work. The number

of engineering projects reported as active in 1924 was 138. This represents a decrease in number of projects as compared with the previous year, but there was a distinct advance in the research character of the projects and an increase in the number of members of the station staffs employed in such work.

PROJECTS

New and increasing demands are being made upon the experiment stations for advice and assistance which can only be provided through research. In the attempt to meet these demands the stations are carrying a total of nearly 5,500 separate projects and employing the services of over 2,300 trained scientists.

Most of the work of the stations has now been placed on a definite project basis. The wisdom of this policy from the standpoint of administration and promotion of effective research has been fully demonstrated. It tends to encourage more specific projects and to reduce or eliminate unproductive efforts.

The actual number of projects reported as active during the year, including 181 carried on by the stations in Alaska and the insular stations, was 5,293 as compared with 5,156 the previous year. Of these 54 were purely administrative service, control, or regulatory, which, if deducted, leaves 5,239 projects devoted to research or experimentation.

The subject distribution of the projects differed little from that of last year. Field crops led with 1,722 projects, followed in descending order by horticulture 919 projects, animal production (including poultry) 638, plant diseases 450, dairy cattle and dairying 301, soils 300, fertilizers 218, rural economics 209, veterinary science 193, agricultural engineering 138, genetics 102, and foods and human nutrition 49. There was an increase during the year of 111 projects under field crops, 25 under fertilizers, 24 under dairy cattle, and 23 under rural economics.

SPREAD OF INFLUENCE OF STATION WORK

The spread of influence of station work has been rapid, not only through the agency of local substations, test farms, and the various extension services, but also through publications and publicity.

Substations.—The growth of effort to extend the benefits of station investigations by making the results more widely applicable to special problems and local conditions is reflected in an increase in substations, local experiments, and like agencies. A recent inquiry as to the number and distribution of such agencies showed that there are now in operation, in addition to the 50 State experiment stations and 4 independent stations, about 125 of what may be properly termed substations and about 180 experimental test or demonstration farms affiliated with the stations. It is evident that such extension of the station experiments meets with popular approval and legislative support, sometimes, however, to the embarrassment of administrative officers and to the neglect of or inadequate provision for other important needs of the stations.

Publications.—The regular publications of the stations have not materially increased in number and volume in recent years, remaining about 500 documents annually. The variety and extent of publication through other channels have, however, vastly increased, the net result being a distinct increase of published output, with a better adaptation of it to different classes of readers.

Since the organization of the first experiment station in 1875, the stations have issued more than 18,000 publications. A bulletin published by the Office of Experiment Stations during the year lists approximately 12,500 of the more important of these publications. This is to be followed by a series of biennial supplements, the first of which appeared in August, 1924, and listed 728 bulletins.

As a rule there has been decided improvement in appearance and subject matter of the station publications. The nature and purpose of the annual report required by the Hatch Act continues to be the subject of much discussion and diversity of practice. There appears, however, to be a tendency to reduce the report in size and make it primarily administrative. There is increasing acceptance of the view that the report is not an appropriate place for original accounts of scientific work but may properly be limited to a concise showing of the progress of the station and how it is discharging its obligations and serving the public.

To guard against waste of publications and to conserve their limited printing funds, some of the stations have abandoned mailing lists except for libraries and workers in similar

institutions, sending their publications only on individual request. Under this plan forthcoming bulletins are announced through the press and by means of post cards. Some of the stations, however, that have tried this plan have returned to the practice of maintaining regular mailing lists corrected at frequent intervals and classified according to the different lines of interest.

The differentiation in the published matter and the channels of publication is not to be taken as indicating any lack of activity in that direction or of obligation to the public. On the contrary, more attention than ever is paid to the proper publication of the station work, to publicity regarding its activities, and efforts to bring the practical results effectively before the farming people. This is believed to be in full accord with the spirit of the clause in the Hatch Act regarding publications. The only distinction is that avenues and agencies are now open for making the work of the stations known which were not in existence at the time the Hatch Act was passed, and this fact has led to a modification of practice the better to suit current conditions.

Relations with the extension service.—Naturally the cooperation of the extension service is relied upon to a large extent to give publicity and application to the work of the stations. Effective cooperation in this respect is dependent upon a recognition of mutual dependence and involves some affirmative action on both sides to maintain helpful relations. As an aid in this direction increased attention is being given to the working out of long-time State and regional programs of research and extension.

PERSONNEL

The difficulty of maintaining a competent personnel is being somewhat relieved. The annual overturn has decreased. Conditions for maintaining a more permanent research force have distinctly improved, and means of securing the advanced training required in research have increased. Graduate courses for investigators and agricultural specialists have increased, particularly in the larger institutions, and opportunities for graduate work for advanced degrees are being more freely provided. These conditions have placed a larger number of trained workers at the disposition of the stations, and the effect has been to raise the standards and the requirements for those engaged in leading lines of investigation.

Some of the more important changes in personnel during the year were as follows:

Changes in directorships.—M. J. Funchess, who had been acting director of the Alabama station, was appointed director. Dan T. Gray succeeded Bradford Knapp as director of the Arkansas station. E. D. Merrill was appointed director of the California station, succeeding C. M. Haring. R. W. Thatcher, director of the New York State station, was made also director of the New York Cornell station. B. W. Kilgore relinquished the position of director of extension and became dean of the school of agriculture at the North Carolina State College, in addition to the directorship of the station. C. T. Dowell resumed the directorship of the Oklahoma station, succeeding M. A. Beeson. C. A. Mooers, vice director of the Tennessee station, was made director. William Peterson, director of the Utah station, was made also director of extension, succeeding R. J. Evans.

Other changes.—W. E. Hinds, chief of the department of entomology, and F. L. Thomas, associate entomologist of the Alabama station, resigned. J. M. Robinson was made acting head of the department, and H. G. Good was appointed assistant entomologist.

A. E. Vinson, chief of the department of chemistry of the Arizona station, resigned. H. Embleton succeeded R. B. Thompson in charge of the poultry department.

W. A. Lippincott was appointed in charge of the poultry work at the California station. Appointments in the grade of associates at this station included D. E. Davis in veterinary science, J. H. Irish in fruit products investigations, and H. J. Smith in entomology. H. E. Van Norman of the dairy department resigned. E. J. Wickson, former director and horticulturist, died July 21, 1923.

A. K. Peitersen, botanist of the Colorado station, died February 23, 1924.

C. M. Slagg, in charge of the tobacco substation in Connecticut, resigned. I. G. Davis was appointed agricultural economist at the Storrs station.

G. H. Blackmon was appointed pecan specialist and E. L. Ayers agriculturist at the Florida station.

D. G. Sullins, in charge of the animal husbandry work at the Georgia

station, resigned and was succeeded by F. R. Edwards.

Changes at the Ilinois station included the appointment of B. Koehler in charge of crop pathology in the agronomy department, the resignation of B. S. Pickett, chief pomologist at the station, and the appointment of V. W. Kelley as associate in pomology, and of E. P. Lewis as associate in olericulture.

The more important changes at the Indiana station were as follows: A. A. Hansen was appointed associate in botany, and D. B. Clark resigned as associate in veterinary science.

At the Iowa station B. S. Pickett was appointed chief in horticulture, and P. H. Elwood, jr., was made chief in landscape architecture. H. W. Johnson resigned as assistant chief in the soils section and was succeeded by H. J. Harper. Paul Emerson resigned as assistant chief in soil bacteriology and was succeeded by L. W. Erdman. F. A. Fenton, associate and assistant chief in entomology, resigned.

Appointments at the Kansas station included A. H. Helder in charge of landscape gardening to succeed W. S. Wiedorn, resigned, H. E. Reed in charge of sheep husbandry, L. F. Payne to succeed W. A. Lippincott in charge of the poultry department, D. C. Warren in charge of poultry genetics, and C. O. Swanson head of the milling department.

T. H. Jones resigned as entomologist of the Louisiana station and was succeeded by W. E. Hinds. R. Dodson was appointed forage crop specialist.

H. F. Tompson, in charge of the Massachusetts market garden field station, resigned.

LeRoy Cady, associate horticulturist of the Minnesota station, died September 11, 1923.

R. F. Howard, chairman of the department of horticulture at the Nebraska station, resigned and was succeeded by C. C. Wiggans.

J. J. Black was appointed poultry pathologist and W. H. Dumont oyster research specialist at the New Jersey stations.

J. M. Sherman was appointed head of the dairy industry department of the New York Cornell station.

Stanley Combs resigned as dairy experimentalist at the North Carolina station and was succeeded by V. M. Williams. J. P. Pillsbury, head of the department of horticulture, was transferred to the college faculty and was succeeded on the station staff by C. D. Matthews. B. F. Brown, chief of marketing, was transferred to the college staff.

Glen McIlroy, of the poultry department of the North Dakota station, resigned and was succeeded by J. R. Redditt. L. R. Holland, in charge of dairy manufactures, resigned.

G. W. Cochran was made head of the department of horticulture of the Oklahoma station and F. M. Rolfs plant pathologist. R. B. Thompson was put in charge of the poultry work.

D. C. Mote was made entomologist of the Oregon station on the death of A. L. Lovett, which occurred in April, 1924. B. B. Fulton resigned as associate entomologist and E. W. Bressman was appointed associate agronomist.

A. K. Anderson was made associate in agricultural chemistry at the Pennsylvania station and W. T. Tapley succeeded W. C. Pelton in vegetable gardening. I. D. Wilson, veterinarian, resigned.

F. T. McLean succeeded H. B. Hall in the department of botany at the Rhode Island station, and F. R. Pember, of the department of chemistry, resigned.

N. E. Winters, in charge of the boll weevil control work of the South Carolina station, resigned and was succeeded by G. M. Armstrong. C. O. Eddy was appointed associate in the department of entomology.

R. E. Hunt, head of the department of animal husbandry of the Virginia station, was transferred to college work.

At the Washington station S. C. Vandecaveye succeeded P. W. Allen as bacteriologist.

ADMINISTRATION

Progress in the development and improvement of methods of administration of research and in coordination of effort are recorded in many cases. There is evidence of a growing appreciation of the need of closer administrative and staff contacts, and of the value of committee work and conferences. The increasing need for inspiring leadership to promote cooperation and teamwork accentuates the importance of close administrative attention to station affairs and argues strongly for the independent station director who can give his attention exclusively to station affairs. The present situation is as follows:

In 20 States there are separate station directors—Colorado, Connecticut,

Georgia, Maine, Maryland, Massachusetts, Mississippi, Nevada, New Mexico, New York, North Dakota, Ohio, Oregon, Rhode Island, South Carolina, South Dakota, Tennessee, Texas, Virginia, and West Virginia. The dean of agriculture is likewise director of the station in 18 States—Alabama, Arizona, California, Iowa, Kansas, Louisiana, Michigan, Minnesota, Missouri, Montana, Nebraska, New Jersey, North Carolina, Oklahoma, Pennsylvania, Vermont, Washington, and Wyoming. In 3 States—Indiana, New Hampshire, and Utah—the offices of director of the station and director of extension are combined. In 7 States—Arkansas, Delaware, Florida, Idaho, Illinois, Kentucky, and Wisconsin—the director of the station is also dean of agriculture and director of extension.

The total volume of station work of the best type was never larger or more promptly put to practical use. Agricultural research has, however, reached a difficult and critical stage in its development which may lead to a decrease in volume of striking and quickly applicable results. The simple problems have in large measure been solved or the means of solution worked out. Discoveries likely to revolutionize practice are less frequent. More profound and complex problems, requiring new technique and methods and deeper and clearer insight into the relations of cause and effect, have been uncovered. Routine applications of conventional methods will no longer suffice. Whether this stage shall mark the beginning of an era of diminishing returns in agricultural research, as has been suggested, will depend upon the attitude of those engaged in the work of both administration and investigation and the use they make of their opportunities and means. As public servants, the station administrators will be depended upon to make the most of the available resources and facilities and to guard against ineffective and unprofitable effort. On the other hand, the individual investigator will be expected to assure himself that his research is growing in effectiveness and not merely increasing in volume without improving in kind.

STATE LEGISLATION AFFECTING THE STATIONS

There was only a limited amount of special State legislation affecting the stations during the year. The following are some of the features of such legislation:

The Kentucky Legislature provided for the establishment of two substations, each on land donated for the purpose. The first was located near Quicksand, Breathitt County, the other at Princeton, Caldwell County. An annual appropriation of $25,000 was provided for the former and $20,000 for the latter.

The New Jersey Legislature provided for the establishment of a poultry disease laboratory at Vineland and appropriated $5,000 annually for its maintenance.

The Virginia Legislature passed a comprehensive act which provided among other things for an agricultural survey of the State under the direction and supervision of the experiment station with the object of developing the agricultural interests and resources of the State.

The Oklahoma Legislature placed an inspection tax on commercial fertilizers sold in the State, the major portion of the funds so derived going to the station. The receipts from this source amounted to between $900 and $1,000 the first year and are expected to increase.

Under a State electrical district law enacted by the Arizona Legislature, two districts were organized and developed with the cooperation of the station.

ADDITIONS TO BUILDINGS AND EQUIPMENT

A large part of the additions to the buildings and equipment of the stations during the year were of the ordinary kind. Many of them, however, were of a kind that evidenced a growing recognition of the need of special provision for investigation which requires more exact control or measurement of environmental conditions and factors—temperature, moisture, light, and air—in the multitude of problems of research in which such control or measurement is a necessity. The tendency is more and more to make provision for this purpose in the original construction of laboratory buildings and plant houses rather than by means of special independent pieces of apparatus or supplementary equipment.

A notable increase in special structures for small experimental animals is recorded—a necessary outgrowth of the great extension in recent years of the use of such animals for research,

especially in nutrition and animal diseases.

Some of the more important additions to station buildings and equipment during the year were as follows:

At the Arkansas station a greenhouse was built, a water system installed at the station farm, and 100 acres of land adjoining the farm was bought for $16,000. Cottages were built on the farm, and considerable improvements were made in draining, fencing, etc.

The California Legislature appropriated $100,000 for the purchase of land and construction of greenhouses at Berkeley contingent upon $50,000 being raised locally. The latter was secured by private subscription, and about 18 acres of land was purchased near the university campus. A new head house was built at the Citrus station at Riverside. At Davis a new field laboratory for truck crops was constructed and equipped, a wing was added to the veterinary building, and a shop building was constructed for the engineering department. Laboratory space was provided for poultry husbandry, and an irrigation system for 20 acres was installed.

A new seed house was built at the Fort Lewis substation in Colorado, and a special appropriation of $4,000 was used for barns and other improvements at the Cheyenne Wells substation. At the Akron substation 154 acres of land was added by purchase.

At the Connecticut Storrs station the construction of a wing to the dairy barn was begun, and a maternity shed was built for abortion experiments. A small building was erected and equipped for indoor chick feeding experiments.

The Florida station reports the addition of small greenhouses and barns at Everglades substation.

At the Georgia station improvements were made in the chemical laboratory, and a sweet potato storage house and a concrete root cellar were built to replace one destroyed by fire.

A part of a new poultry plant was completed at the Illinois station, and construction of a new horse barn, a swine barn, and a central poultry house was begun. Plans for a new dairy manufactures building and a new dairy barn were completed during the year. A respiration calorimeter for animals of any size was built.

At the Indiana station the construction of a unit of the greenhouse for the horticultural and entomological work was begun, and a new building for small animals used in nutrition investigations was provided. A new livestock farm of 442 acres was secured about 3 miles from the station, which is equipped for housing 40 brood sows but can be used for cattle and sheep. The board of trustees accepted a 40-acre experiment field in Marshall County.

At the Iowa station 80 acres was added to the dairy farm, 133 acres for horticultural work, and 10 acres for bee investigations. The poultry department added three permanent laying houses and six movable rearing houses.

In Louisiana the agricultural building on the new site of the university at Baton Rouge approached completion, and a dairy barn and other farm buildings were occupied. Steps were taken to transfer the sugar house work at Audubon Park to the new site at Baton Rouge. A new barn was constructed at the Fruit and Truck substation at Hammond.

Construction was started at the Michigan station on a new horticultural building to cost $250,000, with $75,000 for equipment, and greenhouses to cost $39,000.

A new dairy barn costing $220,000 was completed at the Minnesota station. A refrigerating machine for investigations requiring temperature control was installed.

The new agricultural building at the Missouri station was equipped and occupied.

At the Nebraska station 64 acres was purchased for additional experimental work with beef and dairy cattle.

An oyster research laboratory was established by the New Jersey stations at Bivalve, N. J. A dairy and animal husbandry building was built and equipped at a cost of $200,000, and buildings to house the livestock of the station and college were built at a cost of about $50,000. Two additional farms were purchased, totaling 150 acres, for the horticulture and farm crops departments of the college and station. Considerable additions were made to the station dairy herd.

At the New Mexico station 11 acres of land was added to the horticultural farm, and a number of smaller buildings were constructed for the poultry department.

The new dairy industry building of the New York Cornell station, costing $568,000, was completed and occupied during the year. Plans for a new plant industry building and a new library were completed.

The new agricultural building, Ricks Hall, at the North Carolina station, costing $200,000, was completed and occupied largely by the station. A swine experiment farm of 72 acres near Raleigh was purchased. A new swine plant and central feeding house with other improvements were added to the Black Land substation, near Wenona, and new office buildings, laboratory, and insectary at the Coastal Plain substation, near Willard. A new calf barn, spring house, insectary, and a five-room cottage were built at the Mountain substation, near Swannanoa.

Improvements at the North Dakota station included an addition to the dairy barn, a poultry brooder house, a greenhouse for the agronomy department, and apparatus for the investigation of macaroni wheat.

The new laboratory and office building of the Ohio station to be known as Thorne Hall neared completion. It is to be used for the departments of soils, chemistry, botany, and entomology. The appropriation for this building was $75,000. A forest and park of 5,986 acres was purchased.

At the Oklahoma station a new animal husbandry building with a stock judging pavilion to cost $125,000 was nearly completed. This is to be used partly for station work. A cattle feeding shed was provided for. The dairy building was improved, and the new dairy barn, costing $48,000, was completed and occupied. A sweet potato storage house and a concrete root cellar were built.

At the Oregon station two modern laying houses each with a capacity of 300 hens were erected. Six additional acres were secured for the substation at Talent.

The construction of a beef cattle feeding barn with silo was begun at the South Carolina station. An office building for boll weevil control work was built at the Pee Dee substation.

At the Utah station a new greenhouse was completed and equipped, and the construction of a plant for egg-laying contests was begun. A farm of 86 acres adjoining the Greenville farm was acquired, and a 30-cow dairy barn was built to be devoted exclusively to dairy work.

At the Washington station an additional laying house unit was added to the poultry plant.

The new dairy barn at the West Virginia station was completed during the year. At the Reymann Memorial Experiment Farm a creamery was built and equipped with an ice plant.

The Wyoming station built a shed for horses with paddocks and feed racks at Laramie, added a poultry house at the substation at Torrington, and enlarged the dairy barn at the substation at Lyman.

INSULAR EXPERIMENT STATIONS

The work and expenditures of the experiment stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands were supervised as heretofore by the Office of Experiment Stations under direct charge of Walter H. Evans, Chief of Insular Stations.

These stations were supported by appropriations made directly to the United States Department of Agriculture, as follows: Alaska, $70,000; Hawaii, $50,000; Porto Rico, $50,000; Guam, $15,000; and the Virgin Islands, $20,000. A statement of income and additions to equipment of the stations is given on page 108 of this report. The results of the work of the stations are published in their reports, bulletins, and circulars.

The guiding policy in the work of these stations has been to develop a type of agriculture suited to the varied conditions of Alaska, to diversify the agriculture of Hawaii, Porto Rico, and the Virgin Islands, and to restore that of Guam to its former importance.

The agriculture of Alaska is being developed to supply the growing needs of the Territory. With the varied conditions of soil, climate, and length of season, it is necessary to make investigations along many lines. These include, among others, much adaptation work, which is beginning to show results, and development of selected and hybrid grains, which are proving superior to introduced varieties. In Hawaii the banana and pineapple industries particularly show the influence of the station's work, and the pigeon pea introduced by the station is greatly increasing the forage resources of the islands, as well as improving the fertility of the soil. The influence of work begun by the Porto Rico station to eliminate the cattle tick has been widely extended, with the result that there are now more than 200 dipping vats in use in the island. Many plantations have been freed of ticks and cattle are being rapidly improved. Dairying promoted by the station work is becoming an important industry of the island.

Much of the time and effort of the Guam station during the year was devoted to repairing damage done to the station property by a typhoon and to

attempts to check the spread of the coconut scale, which threatens the leading industry of the island.

The Virgin Islands station has shown the possibility of growing vegetables in considerable variety and quantity if attention is paid to favorable times of planting and proper methods of culture. Larger supplies of local-grown vegetables of better quality are now to be found in the markets.

SOME RESULTS OF STATION WORK

The following are examples of recent contributions in the various fields of station work:

SOILS AND FERTILIZERS

The stations report 300 active projects relating directly to soils and more than 200 dealing with fertilizers. These cover practically every feature of the subject of soil fertility and maintenance, including soil surveys, fertilizer requirements, and correction of infertile conditions. The work is national, regional, State, and local in scope, dealing with both generalized and specialized conditions.

Much of the work with soils has been designed simply to secure empirical results, but more and more it is being directed toward fundamental inquiry into the causes of the observed phenomena and coordinated toward a definite end. For example, in the study of soil acidity which is a widespread condition and of alkalinity which affects in the aggregate a large area of land but is more localized, investigation is going beyond mere tests of the intensity and correctives of such conditions and is undertaking to determine the causes of the conditions and the response of different crop plants to them.

A significant trend of recent work on soils has been in the direction of a somewhat systematic determination of the optimum conditions of soil acidity or alkalinity for different kinds of plants and of the simplest and most efficient and economical means of maintaining these conditions permanently. The Wisconsin station has been especially active in such work, but several other stations are making investigations contributing toward the same end.

Acidity.—The specific causes of soil acidity have been the subject of much investigation by the stations. Investigations by the California station indicate that acid soils are simply normal soils which have lost more or less of their calcium by solution in carbonated water and its removal by leaching or absorption by plants. The Rhode Island station, which attributes the growth-inhibiting action of certain so-called acid soils to soluble aluminum compounds, finds that both lime and soluble phosphates are correctives of the trouble, a combination of the two being especially effective.

Alkalinity.—The movement of soluble salts in soils and their removal by leaching have been studied by a number of stations. It has been observed that attempts to remove alkali by leaching generally develop a condition of impermeability which arrests the process and leaves the soil in bad physical condition for tillage.

Wide variations in the rate of movement of different soluble salts in the soil are observed. The New Mexico station found that nitrates moved more rapidly than chlorides and sulphates in either capillary or drainage water. This station also found that practically no phosphoric acid was lost in drainage water. Approximately 80 per cent of the water-soluble potash was leached out and 50 per cent of the nitrogen was so removed.

Liming.—Station investigations relating to lime as a corrective of acidity and for improving the physical condition of soils have been numerous. To an increasing extent, however, attention is turning to the relation of lime to the solubility and movement of other constituents of the soil. The Tennessee station found that the addition of calcium compounds increased the outgo of calcium salts from the surface soil and subsoil, although the subsoil absorbed some of the calcium salts leached from the surface soil. The addition of magnesium compounds decreased the outgo of lime salts from the surface soil. Applications of lime and magnesia increased the outgo of sulphur from the soil and decreased the outgo of potash.

Much attention has been given to study of the relative efficiency of lime compounds of different degrees of fineness. The Pennsylvania station found that a large part of the coarse particles of limestone applied to soil accumulated in the subsurface without disintegration. The Illinois station found that limestone coarser than 0.05 inch had very little effect during the first two years, and that coarser than 0.10 inch was comparatively ineffective for three or more years.

Nitrogen and nitrates.—The Nebraska station found a very low rate of nitrate accumulation in soils which had been depleted of their organic matter. The California station found that nitrate accumulation is low under grain, alfalfa, or clover, and high under grapes and cultivated crops. The latter station also found that sulphur depresses nitrate formation in the soil. The Georgia station reports that it prevents loss of nitrogen from compost heaps, aids ammonification, prevents loss of free nitrogen, and apparently prevents nitrification.

Manure.—The Utah station found that manure increased the loss of lime from soils, but this effect decreased as the irrigation water applied was increased. The calcium-magnesium ratio was widened by both manure and irrigation water. In a highly calcareous soil to which 5 tons of manure had been applied annually for 12 years the Utah station found that the soil had stored at the end of that period 17.7 per cent of the carbon and the organic matter which had been applied, and where 15 tons of manure had been applied annually 71.4 per cent of carbon was retained. The application of manure tended to widen the carbon-nitrogen ratio, whereas irrigation water narrowed it.

The increasing scarcity of manure has directed attention to possible substitutes for it. Some of the stations are studying the possibility of converting straw and other waste materials into a manure substitute. The Washington station found that straw humification is speeded up by adding sodium nitrate or ammonium sulphate and calcium carbonate.

PLANT PHYSIOLOGY

The study of questions of plant improvement and production has led station investigators far into the field of plant physiology, and the number of noteworthy achievements in this line is rapidly increasing. Some results of recent investigations of this kind are as follows:

Formation of sugars.—Studying the formation of sugars in the leaves of corn and sorghum collected at two-hour intervals, the Kansas station found that the total sugars began to increase between 4 and 6 a. m., reaching a maximum at from 12 m. to 5 p. m., and decreased gradually from that time until daylight the following morning. The nonreducing sugars were in excess of the reducing sugars. The former increased markedly during the day and decreased during the night, while the latter usually showed very little increase, and the amount present at different periods of the day was very irregular. No significant differences were observed between corn and the sorghums in regard to the relationship between reducing and nonreducing sugars in the leaves.

Transfer of nutrients.—The effect of fertilizers, especially nitrate of soda, applied to the soil on one side of a fruit tree was found by the Maryland station to be confined to that side. Apparently there is very little cross transfer of nutrients in certain plants, and the foods elaborated on one side of the plant are used and stored mainly on that side.

Oxidase activity.—A positive correlation of increased oxidase activity with decreasing dormancy in the latter part of the spring was noted by the Minnesota station. A number of water plants grown in gas-tight tanks to which carbon dioxide was supplied under artificial light bloomed in January and February, while under ordinary conditions they would bloom in July.

Temperature effects.—The maximum temperature at which potatoes produced tubers was shown by the Minnesota station to be between 20° and 23° C. Failure to produce tubers at the higher temperature is attributed to an increase in the rate of respiration, consuming the carbohydrates that at the lower temperatures are stored in the tubers.

Water requirements.—The water requirements of corn and sorghum were shown by the Kansas station to vary greatly with varieties, especially in sorghums. No relationship was found, however, between the water requirements of a plant and its ability to withstand drought.

Light effects.—Corn, wheat, and potatoes under constant light, temperature, and humidity showed a uniform rate of growth with no inherent daily periodicity, in experiments at the Minnesota station. There was a relatively constant quantity of starch and other carbohydrates in the leaf. Tobacco plants subjected to a light intensity of about 200 candles (one-twentieth of average daylight) during the day were especially subject to attacks of parasites, and apparently did not accumulate sufficient plant food during the day to maintain their growth. Plants grown under artificial illumination at night produced more growth of tops and stronger

roots than those grown in daylight alone and were less subject to disease. Artificial light seemed to reduce the susceptibility of seedlings to damping off.

Mineral nutrients.—Marked effect on absorption of mineral nutrients by barley was observed in experiments at the California station in which sodium chloride and sodium sulphate were added to the culture solution, the tendency being to decrease the absorption of calcium, magnesium, and potassium. Rapid and extreme changes in the reaction of the sap expressed from the roots were caused by the addition of sodium bicarbonate to the culture solution. Young orange trees showed serious injury when grown in culture solutions to which no calcium was supplied. Trees in cultures to which no potash salts were added made a fair growth and did not show as much injury as those lacking calcium. There was a tendency of the chlorophyll to fade out, and the sap of the leaves was slightly more acid than in case of those receiving potassium. Leaves of trees to which no calcium salts were applied were rich in potassium and, conversely, those receiving no potassium were high in calcium. Where calcium salts were withheld the trunks and roots were the last to be depleted of that ion, and where potassium was withheld the roots and rootlets were last to be depleted of this ion. Experiments indicate that stimulation of the growth and respiration of wheat may be induced by suitable concentrations of sodium chloride under certain climatic conditions.

Iron, manganese, copper, and zinc were found by the Kentucky station to occur in greater concentration in the pericarp and germ of wheat, corn, soy beans, and oats than in the endosperm, so that these substances are removed for the most part in the modern process of milling, with a probable lowering of the nutritive value of the flour produced. This station reported further confirmation of its previous conclusions that manganese is one of the elements necessary in minute quantity to the normal growth of green plants, and that other metallic elements or combinations may function in the same way. Experiments with wheat, oats, and tomatoes suggested that copper and zinc may perform an essential function in the fructification and development of the seeds of plants.

FIELD CROPS

Recent work of the stations on field crops has dealt largely with development of varieties of improved quality and increased disease resistance. This feature of the work is reviewed in the special article beginning on page 43 of this report. Progress is also reported in the study of cultural methods and rotations and various factors which affect the economic value of crops.

Factors affecting composition.—The Utah station found that the content of nitrogen in wheat, oats, and barley decreased and the mineral constituents increased with the amount of irrigation water used. The Kansas station finds that weather is the strongest factor influencing the protein content of wheat, but that crop rotation may have an important influence in this respect. Early preparation of land for wheat increased not only the yield but also the protein content. From studies reported by the North Dakota station, it appears that the most influential climatic factor affecting the quality of wheat is the mean daily temperature of the growing season. A cool season tends to produce a heavy plump grain with a low protein content, while high temperatures and hot winds produce shriveled berries of high protein content. It was observed that use of leguminous crops in the rotation tended to increase the protein content of wheat.

Chromosome numbers.—The Maine station found a high degree of correlation between chromosome numbers and adaptability and economic value of wheat species. Species with 7 chromosomes are of no economic value and are found only in hot tropical regions. Those with 14 chromosomes are of some economic value but not adapted to the making of light bread. They are mostly spring wheats and not suitable for cold climates. Species with 21 chromosomes are of greatest economic value and include the only varieties suitable for making white bread. The possible value of increasing the chromosomes by artificial means and thus improving the quality of wheat is suggested.

Baking quality of wheat.—Studies at the Nebraska station show that high protein frequently fails to correlate with high baking quality, that the wide variation in the baking quality of the wheats of the State is due to differ-

ence in gluten quality or to a factor as yet unknown, that there is no correlation between commercial grades and quality, that the higher protein winter wheats from the more arid regions of western Nebraska are generally of poorer baking quality than the winter wheats of eastern and southern Nebraska, and that quality is improved by the use of legumes in crop rotation systems. It was also found that although proteins from different wheats may differ slightly in chemical configuration, these differences are not a determining factor in flour strength.

Soft corn.—The soft corn problem has received the attention of several of the stations, particularly in the Corn Belt. The Iowa station found that soft corn, fairly mature and only slightly molded, made silage that was palatable, clean, and bright, and of good aroma. The dry matter recovery was higher in dried than in the ensiled corn, but the recovery of protein was highest in the better grades of silage. The cost of ensiling was approximately 13 cents per 100 pounds, and of drying 21 cents. In experiments at the Ohio station it was found that the grain portion of ensiled corn lost a considerable part of its protein, in some cases practically half, the loss being greater when the kernels were broken.

Ensiling versus field curing of corn.—The Missouri station reports comparative tests which showed smaller losses in dry matter but considerably larger losses of protein in ensiling than in field curing.

Disease-free seed potatoes.—Much of the work of the stations on potatoes has centered around the question of means of securing disease-free seed. Preliminary studies at the Oregon station indicate the need of widespread adoption of the seed plat plan for virus disease control as the only means now known by which growers can approach a reasonable degree of success in eliminating this class of troubles.

Inoculation of legumes.—A number of stations are engaged in studies on the effect of inoculation on various legumes. The Arizona station reports that inoculation hastened the maturity of alfalfa from five to seven days and materially increased the yield of this and other legumes. It was noted that inoculation increased the nitrogen content in a number of cases. For example, it increased the nitrogen content of alfalfa from 1 to 9 pounds per ton, that of cowpeas 16 pounds, and of soy beans 2.6 pounds. The Illinois station has found no legume bacteria which can be cross-inoculated on the soy bean.

Succession and rotation of crops.—The effect of one crop upon another in a rotation is being studied by a number of the stations with positive results of much interest. Averaging 10 years' experiments, the Illinois station finds that continuous corn has yielded 24.8 bushels per acre; grown in a 2-year rotation with oats, 35.2 bushels; and in a 3-year rotation of corn, oats, and clover, 43.1 bushels. On similar plats treated with manure, lime, and phosphates, continuous corn averaged 43.8 bushels per acre; a 2-year rotation, 68.7 bushels; and the 3-year rotation, 58.9 bushels. At the Kentucky station the yield of wheat after corn was 9.3 bushels per acre; after tobacco, 16.9 bushels; after soy beans, 10.6 bushels; after oats, 13.2 bushels; and after turning under a crop of cowpeas, 32.2 bushels.

At the Minnesota station wheat following soy beans, red clover and sweet clover, field peas, and corn yielded over 11.7 bushels per acre, while following oats the yield was 4.06 bushels. Flax following corn gave the best yields. The lowest yields were those following timothy and grain crops. Buckwheat lodged badly following the cultivated and leguminous crops, this being particularly bad following potatoes and corn, with low yields. The best yields were obtained following wheat, oats, barley, rye, and buckwheat. Soy beans yielded about equally well following all crops, when they were well inoculated. Following the leguminous crops they lodged considerably and were uneven in maturing. Yields of shelled corn per acre were highest following the legume crops, with the exception of soy beans. Sorghums, soy beans, and timothy following corn resulted in less than 50 per cent of the yields following the other leguminous crops or the grains.

Longevity of weed seeds.—In studies at the Iowa station with seeds buried under out-of-door conditions, those that have survived for 12 years were velvet leaf, jimson weed, horse nettle, catnip, and honey locust. Five-finger lived 10 years, curled dock 9 years, tumbling pigweed 8 years, burdock 7 years, lamb's quarter 6 years, and Dalea, field thistle, and evening primrose 5 years.

HORTICULTURE

Horticulture is second only to field crops in the number of projects under

investigation by the stations. Some representative contributions of the stations in this field during the year were as follows:

Fruitfulness.—The determining causes and possible control of fruitfulness are receiving much attention by the stations. Studying the question of fruit spurs in relation to fruitfulness, the Iowa station observed that fruit spurs make their greatest growth in a few days at the time of blossoming. The length of this growth, in a measure, regulates the quantity and regularity of fruit production. If the growth is uniform in length, especially if it is short, off-year production is indicated, whereas growths of variable lengths indicate regular annual production. Length of the growth can be controlled by pruning, by the use of fertilizers, or by a combination of the two.

The rate of growth of grafted buds when they begin to grow in the spring, which may vary considerably, was found by the Maine station to depend upon inherent properties of the individual buds and not to differences in compatibility with the seedling root. Buds taken from the most productive trees in an orchard and worked on Northern Spy rooted cuttings after 12 years' growth in the orchard at the New York State station showed no advantage over those from the least productive trees. Standard varieties on their own roots proved preferable to the same varieties top-worked on young Northern Spy trees.

In experiments at the New Hampshire station 12-year-old Oldenburg (*Duchess*) apple trees shaded for two seasons showed almost no fruit bud formation, while unshaded trees showed about 65 per cent fruit bud formation. Ringing was found to increase fruit bud formation. It is concluded that the effects of shading in decreasing and of ringing in increasing fruit bud formation are in accord with the theory of the relation of carbohydrates and nitrogen to growth and reproduction. The Indiana station found that cutting back young trees delayed the formation of fruit spurs and fruit buds and thus delayed fruitfulness. Unpruned or lightly pruned trees produced more fruit than trees which had received heavier pruning. In experiments at the Kentucky station heavy pruning of apples delayed bearing, was unfavorable to the set of fruit, and greatly increased the amount of pruning required later because of the thick tops resulting from the cutting back.

Studies at the Maryland station on the relation of pruning to the root development of the grape show that, contrary to the usual idea, heavy pruning does not promote root development, the best development being found with the lighter pruned vines. Fruit buds in the middle of the cane gave higher yields than those on other parts. In a comparison of cane and spur pruning at the Nebraska station, there were a higher percentage of productive buds, a slightly larger number of clusters per productive bud, and slightly larger clusters in the cane-pruned plants.

Fertilizing orchards.—The question of the actual value of fertilizers for orchard fruits under ordinary conditions is being studied by a number of stations. The New York State station, summarizing the results of a long series of tests, concludes that in apple orchards on the better soil types of that State, with clean cultivation, the use of commercial fertilizers is not justified from an investment standpoint, although with some other fruits, especially cherries, the application of available nitrogen may be beneficial. Orchards in sod or in poor soils or those not properly cared for will respond to fertilization.

Fifteen years' tests at the Pennsylvania station have shown that the apple orchards of that State may be kept permanently and successfully in sod, provided the resulting nitrogen deficiency is made up by early spring applications of nitrogenous fertilizers and a heavy growth of grass is obtained and used as a mulch. Applications of nitrate of soda to orchards in sod increased the growth, vigor, and yields. Applying the nitrate before the blooming season, namely, about the time the leaf buds break, has given larger yields than applications made immediately after the blooming season. In experiments at the Delaware station fertilizers delayed ripening and coloring but increased the size of apples. Trees receiving only nitrate produced smaller fruit than those supplied with a better balanced fertilizer. Trees receiving nitrogen were the first to shed their leaves in the fall, an undesirable feature from the standpoint of fruit bud formation.

In fertilizer experiments with peaches at the West Virginia station nitrogen was the only element that increased vegetative growth and yield of fruit sufficiently to be of any eco-

nomic importance. Application of nitrate of soda or stable manure delayed the maturity of the fruit from eight to ten days or more, depending on the season and the quantities applied. Fertilizers had no marked effect in increasing the size of the fruit. Nitrate of soda and manure increased the yield but not the percentage of fancy or extra fancy fruit. None of the fertilizers had a marked effect on the percentage of fruit buds formed. Trees receiving nitrate produced larger leaves and denser foliage than those not so treated, but the fruit was poor in color, largely as a result of shading.

Effect of place of origin of apples.—The New York State station reports that Baldwin apple trees from 40 different localities in the United States now in bearing at the station produce fruits similar in size, color, season, and quality, showing that strains have not originated necessarily because of difference in environment.

Sex in strawberries.—Pollination experiments at the Vermont station indicate that the sexual nature of the strawberry is hereditary, since in both open and self-pollination trials with perfect varieties the progeny were nearly all perfect, whereas in the open pollination of imperfect varieties only about half of the progeny were perfect. Observations on the breeding of perfect and imperfect varieties show that it is possible, in some cases, by careful selection, to introduce the missing sex into an imperfect variety without materially changing its characteristics. Sterility in the strawberry, as now understood, appears to be largely a matter of sex inheritance.

Fruit products.—The important question of the utilization of surplus fruit and by-products is receiving much attention by several stations, notably those of California, Illinois, and others. The Delaware station has recently reported some especially noteworthy investigations on the effect of varying proportions of sugar on the texture, flavor, and yield of fruit jellies. There appears to be no specific amount of sugar that must be added to insure the successful formation of a jelly, but, other conditions being equal, a weak jelly results from too much and a tough jelly from too little sugar. Although the proportion of sugar added may vary over a wide range, the percentage of sugar that exists in the finished jelly is fairly constant at about 69 per cent. The function of the sugar may be that of a dehydrating agent, while the acid is believed to control the precipitation of the pectin in jelly form. The formation of fruit jellies could not be correlated with the total acidity, but there was a direct relation between jelly formation and active acidity or H-ion concentration, the minimum at which this occurred being pH 3.46. Jelly formation occurred irrespective of the quantity of pectin present, once the minimum H-ion concentration was attained, but the quantity of pectin had to equal the minimum amount that was necessary to produce a jelly. With pectin, sugar, and water maintained constant, the character of the jelly was determined by the H-ion concentration, the jelly being stiffer as this increased.

PLANT DISEASES

The work of the stations on plant diseases is extensive and varied. Recently special emphasis has been placed upon immunity and the development of resistant varieties and strains of plants, varying virulence of different strains of the diseases, and conditions favoring the spread or control of diseases. Such widespread and destructive diseases as the so-called degeneration diseases of potatoes, and rusts, smuts, and rots of cereals have claimed a large share of attention, and substantial progress in their control is recorded.

Potato diseases.—Recent work of stations on mosaic and other degeneration diseases of potatoes has emphasized especially the varying manifestations of these diseases under different environmental conditions and with different varieties. The Nebraska station has observed that temperatures above 70° F. tend to decrease the number and severity of symptoms of mosaic and that under field conditions mosaic is more severe with early plantings, while spindle tuber is more in evidence in late plantings. Short periods of four to eight days of high temperature and increased sunlight were found sufficient to eliminate the leaf symptoms of mild mosaic and to decrease those of the more severe type. The Utah station found the symptoms to vary in different varieties and observed two distinct forms of the disease, one showing definite mottling with little or no dwarfing and one with prominent mottling, crinkling, and dwarfing.

Earlier work of the Maine station showed aphids to be active carriers of mosaic. Later observations indi-

cate other transmitting agent in addition to aphids.

In extensive studies of diseases attacking the potato tuber internally, the North Dakota station found that the blackleg bacillus, as well as the Fusarium wilt fungus, is a very common cause of stem end discoloration and that both of these organisms may be present in the same tuber. A large number of discolored tubers was found from which no organism could be isolated. Removal of the stem end of seed tubers is urged as a control measure.

Cereal diseases.—The work of the stations on cereal diseases is very extensive, a large part of it being done in cooperation between different stations and with the Office of Cereal Investigations of the United States Department of Agriculture. There appear to be several types of resistance to rust (*Puccinia graminis*) in wheat according to the Minnesota station, which also reports that fertilization with phosphorus and potash appears to enable the plants to withstand attacks of the disease.

The Indiana station has reported the alternate hosts of various cereal rusts and has shown that the leaf rusts of wheat, rye, barley, and corn are distinct from similar rusts on wild grasses, each apparently being restricted to the one cereal. The station considers the development of resistant varieties to be the most promising method of control. Of the wheats, the durums and emmers, as a group, are outstanding in resistance. A number of pure resistant strains have been developed, which, however, produce little or no seed when selfed and are of undetermined practical value.

The recent work of the Washington station, among others, on inheritance of smut resistance and on breeding of smut-resistant varieties is noteworthy. This station has demonstrated that smut resistance is definitely heritable, thus making possible the certain production through breeding of smut-resistant varieties.

The value of copper carbonate dust for control of cereal smut has been studied by a number of stations. The Oregon station found that high-grade dust containing 50 per cent or more of copper, when properly applied, controlled bunt in wheat, while low-grade dusts containing only 10 to 22 per cent of copper were less effective, especially when the wheat was heavily smutted. The California station found that copper carbonate dust applied to seed wheat at the rate of 2 ounces or more to the bushel effectively controlled bunt when the seed was not blackened with spores, and that the treated seed was not injured even when held in storage for an indefinite period. Bluestone powder was also found to be effective. Comparing copper carbonate and formaldehyde treatment, the North Dakota station found that the chief damage done by formaldehyde to germination resulted from too rapid drying of the seed. When the seed was placed in soil moist enough to bring about immediate germination no harm resulted. In dry soil seedlings from seed treated with formaldehyde did not grow as well as those from seed treated with copper carbonate dust. The New Jersey station secured the best control of oat smut with formaldehyde, with nearly as good results from copper and nickel carbonate.

The Minnesota station found various types of wheat, barley, and many grasses susceptible to wheat scab due to *Gibberella saubinetii*, but oats only slightly so. By artificial infection the organism was found to cause a seedling blight of flax, clover, tomato, radish, pea, and cucumber; a stem rot of squash, bean, tomato, cucumber, pea, and sunflower; a rot of apples, carrots, and potato tubers; and also a root rot of beans. Crop rotation slightly reduced the amount of disease. This station has also made extensive studies of diseases caused by *Helminthosporum sativum*, including leaf spots, root rots, foot rots, seedling blight, and discolored seeds of wheat, barley, rye, and many grasses. These studies have shown a wide range of susceptibility and of host plants of these diseases, which are extremely hard to control. Rotation helps to reduce disease, but does not eliminate it. Resistant varieties are thought to offer the most promising means of control.

Much work has been done by a number of stations on corn rots of various kinds. Observations at the Indiana station indicate that the root rots do most damage in soils deficient in available phosphates and potash and that the addition of these often corrects the trouble. Ear rots appear to be largely dependent upon climatic conditions in the fall. The Iowa station found that *Diplodia zeæ* causing dry rot of corn is not systemic and does not grow into the plant from infected seed, that heavy rainfall at the end of the growing period favors the development of the disease, and

that Diplodia-infected seed is difficult or impossible to detect except by germination tests. A long rotation, the early field selection of seed, and seed germination tests in the spring are considered to be the most promising means of control. Dry rot, due to *Basisporium gallarum*, was found by this station to infect the corn plant locally, rotting the fibers of the shanks and causing infected ears to break off easily. The temperature limits for the growth of the organism were found to be between 10° and 40° C., with an optimum of 25°.

Sugar beet diseases.—The extension of sugar beet production appears to depend in many cases upon the possible degree of control of insect-borne diseases. Some of the stations are, therefore, studying the dissemination of such diseases by insects. The California station has found that leafhoppers, not previously infected with curly leaf of sugar beets, transmitted the disease after being allowed to feed for two hours on diseased beets. A number of weeds of the Chenopodeaceæ family were found to serve as food and breeding plants for the leafhoppers, and a number of other weeds were found to harbor them under natural conditions.

Sweet potato diseases.—Rots of various kinds are responsible for large losses of sweet potatoes. The New Jersey stations found that fertilizers applied in the row increased the losses from stem rot somewhat in proportion to the size of the application.

Disease of tobacco.—Mosaic, angular leaf spot, and wildfire are among the very destructive diseases of tobacco which have been investigated by a number of stations. The Connecticut station found that tobacco mosaic overwinters on the bull nettle and ground cherry, and that a necessary protective measure is to remove these weeds from the plant bed and its surroundings. Of the plant beds examined by this station, 90 per cent were found to be infected with angular leaf spot, the source of infection in all cases being tobacco juices spit upon the young plants at weeding time. The Connecticut and Virginia stations have worked out and put into practice effective methods of controlling tobacco wildfire, depending mainly upon sterilization of seed, soil, and cover and other parts of the seed bed and the avoidance of the use of any infected tobacco or other refuse in the bed.

Conditions favorable to pole burn or shed burn of tobacco were found by the Pennsylvania station to be failure to wilt stalk-harvested leaves, especially those cut immediately after a rain and before hanging them in the shed, too close hanging, insufficient ventilation, and rainy or foggy damp weather, especially when it is also warm. The use of artificial heat at critical times effectually prevents pole burn.

Cotton diseases.—Texas root rot, a destructive disease especially of cotton, has been found by the Texas station to be capable of attacking a great number of field crops, truck crops, fruits, forest trees, shrubbery, and ornamentals. The peach crop is highly resistant and the pecan wholly so, as are all of the grain and cereal crops. There appears to be but slight difference in resistance of the various varieties of cotton. The causal organism has been definitely determined to be *Phymatotricum omnivorum.* It requires a living host on which to winter over, and infection is active both during the winter and the summer months. It is spread underground by root contact. Control methods recommended consist in eliminating from the soil all living susceptible roots during the fall and winter months by frequent cultivation, plowing when the soil is dry, and using a system of fallow and rotation with nonsusceptible hosts, and by the elimination of all weed carriers.

Fruit diseases.—An example of effective station work on fruit diseases is furnished by various investigations on apple blotch. The Pennsylvania station found that the time of infection with this disease is variable from year to year, the probable limiting factor being precipitation. Tests at the New Jersey station indicated that the disease can not be controlled by the regular spray schedule, especially where it is severe. Three additional applications of commercial concentrated lime sulphur at seven-day intervals following the fifth summer spray made four or five weeks after petal fall gave the best control. In tests at the Indiana station very weak Bordeaux sprays were effective, the early petal-fall spray being especially necessary.

The relation between resistance to brown rot in the plum and mechanical texture and crude fiber content was established by the Minnesota station, those varieties having a tough skin and firm tissue being the most resistant; but this changes from one period of ripeness to another. All varieties have the mechanical properties of resistance when only half grown,

and all have the mechanical properties of susceptibility when overripe.

Tomato wilt.—Much especially noteworthy work on tomato wilt has been recently reported by the stations. Five strains of *Fusarium lycopersici* have been isolated from wilted tomato plants by the Utah station. One of these has proved definitely pathogenic and is being used as a basis for the production of resistant forms. The Missouri station found that the fungus will grow in only a limited range of acidity and that a minimum of wilting occurred in soils of which the reaction was approximately that of the cultures in which minimum wilting occurred, suggesting the possibility of artificially producing soil reactions unfavorable for wilt.

ENTOMOLOGY

The entomological work of the year covered as usual a wide range. A few examples of this work were as follows:

Apple tree leaf roller.—As a result of studies on the apple tree leaf roller the Montana station found that in case of severe infestation this insect may be effectively controlled by use of miscible oil applied when the eggs hatch in the spring. The New York State station found that in some seasons the larvæ of this insect continue to emerge over a period of four to six weeks and that it is necessary to apply arsenicals at rather short intervals during this period, beginning with the prepink stage, in order to keep the new foliage of the terminal growth, leaves, and fruit clusters thoroughly coated with the toxic material. The Washington station found that the leaf roller shows a variety preference, 5 per cent of Rome Beauty being injured, 10 per cent of Jonathan, and 20 per cent of Delicious. Oil sprays were much more efficient than calcium arsenate, the lighter oils being better than those of medium or heavy viscosity.

Oriental fruit moth.—Experiments with the oriental fruit moth at the Virginia station showed that 40 per cent nicotine sulphate is decidedly toxic to eggs and hatching larvæ of the moth.

Trumpet apple leaf miner.—The trumpet apple leaf miner (*Tischeria malifoliella*) was the subject of extensive studies at the Iowa station with reference to life history, food plants, and control. It was found that ordinarily the usual spray schedule for apples, with the aid of natural enemies, keeps this pest in check.

Citrus aphid.—A new citrus aphid, reported by the Florida station, was identified by the Maine station as *Aphis spiræcola*. Its primary food plant is Spiræa, but it migrates to many other plants. Various parasites have been noted, but artificial control has not yet been very successful.

Strawberry crown borer.—While the strawberry is the usual host of the crown borer, the Tennessee station reports that the adults will feed on the blackberry, and the insect has been reared experimentally on the Indian strawberry (*Duchesnia indica*). In a normal year the adult beetles make their appearance and become actively engaged in ovipositing about the first week in April (in Tennessee), and egg laying continues to the end of September, while larvæ may be present from April to the last of November. Hibernation takes place in the adult stage in the strawberry patch beneath leaves and rubbish. The life cycle is generally one year.

Red mite.—The European red mite was found by the Connecticut State station to pass the winter in the egg stage on smaller twigs and branches. Eggs hatched in April or May. The incubation period of the summer egg varies from 6 to 13 days and the adult develops in 5 to 10 days. Adults live 6 to 19 days, and adult females lay 16 to 34 eggs during their lives.

San José scale.—The use of oil sprays was found by the New Mexico station to be more efficient for the control of San José scale than lime-sulphur wash. At the Illinois station summer applications of oil emulsion in addition to the dormant application proved better than the latter alone in the control of the scale.

Woolly aphis. — Paradichlorobenzene one-fourth to one-half ounce and pine tar creosote 1 quart gave temporary control of the underground form of the woolly aphis in experiments at the Tennessee station.

Mexican bean weevil.—In control of the Mexican bean weevil and other insects, sodium fluosilicate gave promising results in experiments at the Tennessee station, being both a contact insecticide and a stomach poison. It is not as poisonous to man as arsenicals. At the Alabama station it was found that the adult beetles show no preference between different varieties of *Phaseolus vulgaris*. Butter beans (*P. lunatus*) possess nearly the same attraction, but infestation of eggs and larvæ develop more slowly. Cowpeas may be at-

tacked. The beetle was economically controlled by dusting with a mixture of calcium arsenate, sulphur, and hydrated lime, 1:1:4. At the South Carolina station the poisons which gave the most encouraging results were magnesium arsenate mixed with 3 to 5 parts of hydrated lime and calcium arsenate with 9 parts of lime, applied as a dust. Lead arsenate gave good control but burned the foliage slightly.

Cabbage root maggot.—Satisfactory control of the cabbage root maggot was secured by the Pennsylvania station by the use of corrosive sublimate, 1 to 1,000. At the New York State station it was found that treatment of cabbage seed beds for maggot with corrosive sublimate solution also protected the plants from attacks of Rhizoctonia and blackleg. Both these and clubroot, as well as the maggot, were successfully controlled by the use of a 1 to 1,280 solution applied three times. Screening the seed bed with cheesecloth will control the maggot but this produces more succulent plants that are subject to Rhizoctonia. This also applies to the use of tobacco dust, which, although effective against the maggot, encourages the growth of Rhizoctonia.

Potato insects.—The favorite food plants of the potato leafhopper during the late fall after potato plants disappear are, according to the Minnesota station, boxelder, apple, rhubarb, and curly dock. In the spring, however, the adults feed almost exclusively on apple and rhubarb. Egg laying begins about June 17 and reaches a maximum by the latter part of June, the nymphal period extending from June 21 to July 15. Adults of the second generation become very abundant about July 17 and continue to increase in numbers until the latter part of the month. Eggs are laid over the period from July 20 to September 1, and overwintering adults develop from these until the middle of September.

The development of hopperburn on potatoes according to the Iowa station is dependent to a large extent upon the date of planting, due to the fact that the female leafhoppers prefer partly grown plants for oviposition rather than smaller vines at the time of the spring flight. Greatest tolerance of the disease was shown by potatoes of the Rural New Yorker type. The rate of development of hopperburn on individual leaflets was determined by the size and succulence of the leaf and not by any inherent resistance.

The green peach aphid, which is a pest of the potato, was reported for the first time, by the Maine station, as wintering in that State, a small but typical spring colony being found on the Canada plum (*Prunus nigra*). Vigorous spring colonies of the buckthorn aphis (*Aphis abbreviata*), which attacks the potato, were found on Rhamnus bordering the potato field, showing that this plant may serve as an overwintering host.

Sweet potato weevil.—Studies on the sweet potato weevil at the Louisiana station showed no clear-cut generations, but there appeared to be at least eight broods during the year. Wild morning glory and tie vines were found to be host plants, especially the large-rooted perennial morning glory (*Ipomœa pandurata*), which appeared to be as acceptable as the sweet potato. Infested seed potatoes are the most common medium of dissemination, the natural spread being very slow. Control studies of this insect at the Texas station showed that there are no parasites or predacious enemies that are of economic importance, and artificial methods of control must be used.

Squash insects.—The squash ladybird beetle, according to the Virginia station, passes the winter in the adult stage chiefly on the trunks of trees and begins to emerge from hibernation about May 20. The first eggs are laid the second week in June and hatch in seven or eight days. In late August the second brood beetles emerge, the first brood overlapping. The chief injury is inflicted by the larvæ of the first brood during the latter half of July and the first half of August. The pickle worm, which attacks especially squashes, cantaloupes, cucumbers, and muskmelons, was found by the Missouri station to show a special preference for summer squash, which when grown as a trap crop with cantaloupes, almost wholly protects the latter.

Alfalfa weevil parasite.—The parasitic hymenopter (*Bathyplectes curculionis*), an enemy of the alfalfa weevil, introduced in cooperation with the United States Department of Agriculture in 1921, has, according to the Nevada station, become fully established and is now present in all infested fields, promising to be an important factor in reducing the number of weevils.

Corn root worm.—Studies on the southern corn root worm by the Louisiana station showed injury to be more se-

vere in early plantings, from the middle of March to the middle of April. The worms were found in the roots of volunteer oats in the spring. Apparently larvæ that injure young corn come from eggs that are deposited in grasses before the corn is planted.

Cotton insects.—A number of studies of cotton insects were reported. The Kentucky station used arsenates of lime and lead successfully in the control of the cotton worm. The Arkansas station recommends destruction of the boll weevil in hibernation and the growing of early cotton. Early infestation was controlled by use of calcium arsenate dust. The Texas station reports that the so-called "rough skinned" weevil, which ordinarily breeds on the morning glory, was found to be injuring cotton by cutting off the lower leaves. The cotton hopper (*Psallus seriatus*) was found to be doing considerable damage in southern Texas, especially on land previously planted to corn or oats. It appears that the greatest injury occurs where favorable host plants are found in early spring, thus permitting the insects to multiply and become abundant when the cotton is young. At the South Carolina station this insect, comparatively new in the State, was found doing considerable damage to cotton. It causes the young terminal bud and terminal leaf to wither, turn brown or black, and drop off, resulting in a failure of the squares to develop. The insect is of the sucking type, which makes poisoning impossible.

Miscellaneous.—Studies on the Hessian fly at the Kansas station indicated that development of varietal resistance furnishes one of the most promising means of combating this pest.

The Japanese beetle can, according to the New Jersey station, be cheaply and efficiently controlled by killing the larvæ in the soil with carbon bisulphide used at the rate of 1 pound per cubic yard of soil under favorable conditions of exposure and temperature.

The pale western cutworm, according to observations by the Montana station, varies in abundance with the rainfall of May, June, and July of the year preceding the outbreak. If the rainfall is less than 4 inches for these three months, the cutworms will probably be found in increased numbers the next year, but if the rainfall is more than 5 inches, the insects will be reduced in number the next season.

Nematodes were controlled at the Florida station by the use of velvet beans as a summer crop, with cultivation and hoeing. By this means numbers were so reduced that the land could be successfully used for vegetables which are highly susceptible to nematode attack.

Beetles and weevils infesting stored seed were effectively controlled by the copper carbonate dust treatment, at the California station. The Minnesota station found that a temperature of 64° C. retards the development of the bean weevil and a temperature of −10° for 12 hours was fatal to all stages. It was found that the spider beetle (*Ptinus fur*) resisted very low temperatures and survived the coldest weather in open warehouses.

Tobacco insecticides.—The discovery of a high yielding, high nicotine tobacco, *Nicotiana rustica*, with commercial possibilities for insect control is reported by the Pennsylvania station. It was found that the nicotine content can be increased by topping or suckering the plants during their growth. The nicotine is easily obtained by pulverizing the plant, steeping in cold water or heating to boiling, and filtering. Such solutions diluted to a concentration of 0.06 to 0.2 per cent nicotine, with the addition of soap, showed marked aphicidal properties.

When acid arsenate of lead was mixed with lime-sulphur to form a combination spray, the New York State station found that undesirable chemical changes took place which could be prevented by the addition of tobacco dust, and at the same time the nicotine in the tobacco dust was dissolved and rendered readily available for insecticidal use.

ANIMAL PRODUCTION

Animal production is exceeded only by crop production and horticulture in the number of projects of investigation reported by the stations. These projects deal with fundamental questions of genetics and nutrition as well as the more practical features of breeding, feeding, and care of all classes of farm livestock. The progress and present status of station work in animal genetics are reviewed in the special article beginning on page 67. Some recent contributions to the subject of animal nutrition are as follows:

Animal nutrition.—Much of the more advanced work in animal nutrition has been along the lines of effect of plane of nutrition, energy requirements, and relation of light, vitamins, and mineral matter to nutrition.

Studies of undernutrition of steers at the New Hampshire station, in cooperation with the nutrition laboratory of the Carnegie Institution, indicated that such vital activities as pulse rate, heat production, glandular secretion, and physical activity decrease with reduced ration, the reverse being true with fattening rations. Nearly four months of undernutrition in no case impaired health, and there was no evidence that it limited the regain of flesh and fat lost. The rate of regain in steers which were brought through a whole winter on a 50 per cent maintenance ration was exceedingly rapid, the original weight being recovered in less than three months on pasture grass alone.

Rations high in protein were found by the New Hampshire station to be particularly uneconomic for fattening, the amount of protein that a mature steer assimilates daily being relatively limited. The Pennsylvania Institute of Animal Nutrition in cooperative studies with a number of stations found that normal growth can be made by cattle on rations containing an appreciably smaller proportion of protein to nonnitrogenous nutrients than is specified by Morrison's latest revision of the Wolff-Lehmann feeding standards. Allowing 0.6 pound of digestible protein for maintenance, the additional protein requirement for milk production was found to be about one and one-fourth times the protein content of the milk. The maintenance requirements of dry cows was found to vary from 4.15 to 5.57 therms of net energy per 1,000 pounds of live weight.

The basal heat production per square meter of body surface of fowls was found by the Illinois station to be nearly the same for birds varying in age from 2½ months to 1 year but decreased progressively per kilogram of body weight with the age of the bird. For birds slightly over a month old it was much greater both per square meter of body surface and per kilogram of body weight than with older birds. The heat production of cockerels was distinctly higher than that of pullets and capons, and that of pullets was generally higher, especially at the older ages, than that of capons. The heat production of cockerels per square meter of body surface was 849 calories, of pullets 807 calories, and of capons 768 calories. A formula for calculating basal heat production per square meter of body surface is proposed as follows: $S=5.86\ W^{.5}\ L^{.6}$ in which S is the surface in square centimeters, W the live weight in grams, and L the distance from rump to shoulder in centimeters.

The ash of the entire bodies of calves from dams on different planes of nutrition was found by the Missouri station to be constant in composition and, with the exception of phosphorus, not correlated with the condition of the dam. The mineral content of lean and fat was not influenced by age or condition. The mineral content of the internal organs decreased in the older animals but was apparently not affected by the method of feeding. The mineral constituents of the blood were fairly constant for all ages and groups. All of the mineral constituents of the skeleton showed an increase in the older and in the well-fed animals. The calcium and phosphorus content of the entire body increased somewhat in the older animals. The Washington station found that variations of sodium in the feed has a decided influence on the growth and condition of the animal. The sodium level, below which growth is retarded and above which it is continued, appears to be very distinct. Animals receiving the smaller quantities of sodium grew rapidly for a short time and then declined in weight, many of them dying comparatively young, while those receiving the larger quantities continued to grow in good health.

The quality of light was found by the Nebraska station to have an especial influence on calcium and phosphorus assimilation by chickens. Light coming through common window glass and deprived of most of the short or ultra-violet rays did not possess the catalytic power necessary for calcium or phosphorus absorption. An exposure to sunlight for 45 minutes a day made the difference between success and failure in growing chickens fed standard rations. In the absence of proper light conditions 3 per cent of cod liver oil added to the ration had the same influence on calcium and phosphorus absorption as sunlight. Chicks exposed to sunlight or ultra-violet rays at the Illinois station did not need antirachitic vitamin D, but chicks fed a basal ration with all the necessary vitamins supplied made as good growth in complete darkness as those exposed to light.

A group of calves kept by the Minnesota station for a year on a ration practically free from antiscorbutic vitamin showed no bad effects, while on

the same ration guinea pigs died from scurvy within 20 days. The requirement of the growing calf for this vitamin appeared to be small. Calves fed whole milk as the sole diet died of tetany within three or four months. This was prevented by adding calcium carbonate to the ration which, however, did not prevent the later appearance of a ricket-like trouble, and neither was the trouble prevented by adding vitamins A, B, or C to the milk diet. Cod liver oil lost its value as a preventive of leg weakness in chickens, in experiments at the Connecticut Storrs station, when mixed with dry feed stored for six months. The minimum amount of antirachitic substance required by chicks was supplied by a quantity of cod liver oil not exceeding 0.5 per cent of the total food intake.

Those organs and tissues of animals which are considered high in vitamin potency were found by the Kentucky station to have a greater concentration of iron, manganese, copper, and zinc than the parts considered low in vitamins. Mature pigeons maintained normal weight for seven weeks and some gained weight on rations low in vitamins, to which one or more of these mineral substances were added.

Some examples of the more practical work of the year in animal production are as follows:

Cattle.—The economy of using younger cattle in the feed lot was indicated by experiments at the Nebraska station. Young animals made more economical gains for feed consumed, could be held over a longer period in case of adverse markets, and the initial cost was less than in case of older animals. The Texas station found that under like conditions 2-year-olds gained more per steer but less per 1,000 pounds of live weight than yearlings. The average cost per 100 pounds of gain was greater for the older steers. Hogs following the steers gained more per steer with the older animals but little more in proportion to the total quantity of corn fed. The conclusion was reached that it is cheaper to ship the steers to where the feed is grown than to pay freight on feed to a convenient feeding place. At the Arizona station 3-year-old steers fattened more rapidly, reached a market finish more quickly, and produced a greater net return than did 2-year-olds when fed a ration of corn silage, alfalfa hay, and cottonseed meal.

Velvet beans were found by the South Carolina station to be a cheap and effective substitute for cottonseed meal for all classes of beef cattle.

Chamiza (*Atriplex canescens*) was shown by the New Mexico station to have a high carrying capacity as a range feed over an extended period of time, to give good succulent feed for cattle in winter as well as in summer, and to sustain a cow and enable her to produce a normal calf. The plant is so high in protein that no protein supplement is needed when pasturing on it. Experiments to establish stands of chamiza on the range indicated that it may be possible to obtain a stand without irrigation and at small expense.

Baby-beef calves can be successfully fattened in Minnesota entirely on home-grown feeds, according to the Minnesota station. Ground ear corn was used successfully and profitably in comparison with a mixture of shelled corn and oats or shelled corn alone. It did not pay to grind shelled corn for the purpose. Corn silage was used to advantage only when the grain ration was supplemented with a high protein concentrate.

Sheep.—The combined returns from lambs and wool in a grade fine-wool flock of sheep was greater, in experiments at the Pennsylvania station, when ewes were bred to mutton rams and all lambs marketed than when the ewes were bred to fine-wool rams. The lambs fattened more quickly and were more desirable for market purposes than those sired by fine-wool rams. The Ohio station found that if early spring lambs are to be raised from Merino ewes it is more profitable to breed them to Southdown than to Merino rams. Because of the early maturing qualities of the Southdown the cross-bred lambs made more rapid and economical gains and produced heavier, fatter, and better developed carcasses at an early age than the Merino lambs. The cross-bred lambs commanded a higher price and yielded a larger ratio of dressed carcass to live weight.

The importance of having ewes in good physical condition at lambing time was emphasized in experiments at the Nevada station. Special efforts to secure increased milk flow during the lambing period were of less importance than good general physical condition at the beginning of the period. The Montana station showed that as a maintenance ration for

breeding ewes alfalfa hay alone is as effective as when supplemented with grain or silage. Cottonseed cake did not improve the alfalfa ration and increased the cost of feed.

Rotative grazing on a plan by which sheep do not go on a pasture until the grass has made a good growth was shown by the Nevada station to greatly increase the carrying capacity.

Barley proved to be an economical and profitable supplement to a ration of alfalfa hay for finishing lambs for fall shipment, in experiments at the Nevada station. The addition of linseed meal to a corn and alfalfa ration caused an increase in the rate of gain, a slight increase in the cost of gain, but a large profit per lamb, in tests at the Nebraska station. The addition of alfalfa-molasses meal to a corn and alfalfa hay ration increased slightly the gains made. Addition of oats to a ration of corn and alfalfa hay was of no advantage. Alfalfa hay gave larger gains and more profit than prairie hay. The Oregon station demonstrated that high class finished lambs can be produced with home-grown feeds—alfalfa supplemented by native grains. Alfalfa hay and shelled corn as a standard ration excelled soy bean hay and shelled corn in rate of gain and quantity of feed required per 100 pounds of gain, in experiments at the Illinois station. Soy bean oil meal and linseed meal were about equally effective as supplements. Experiments at the Indiana station indicated that soy beans have a high feeding value for lambs.

Silage rations produced more rapid and economical gains than corn stover rations, in experiments at the Indiana station. Ear corn was apparently as valuable as shelled corn for fattening lambs. At the Washington station lambs receiving rations containing silage made more rapid and greater gains than those receiving hay alone as a roughage. At the Texas station it was found that ground threshed milo and kafir produced practically the same gains as ground shelled corn when fed in the same quantities as corn for fattening lambs, and the gains were made at less cost.

Swine.—In studies of the effect of early breeding of sows the Missouri station found that well-fed and well-developed sows bred at 6 to 8 months of age and twice a year thereafter produced more pigs at less cost than sows producing their first litters at 18 to 20 months of age, and that the pigs developed about as rapidly and were ready for market at nearly the same age as those from later bred sows. Breeding very young sows, however, retarded their growth.

Pigs stunted by insufficient feed were found by the Utah station to recover and make rapid and economical gains. Such pigs made gains in 25 per cent less time and on 17 per cent less feed than pigs full fed from the beginning. The Kansas station showed that exercise exerts a material beneficial effect upon the strength, thrift, and growth of pigs.

A ration of corn, soy beans, and a mineral mixture of acid phosphate, wood ashes, and salt, produced as rapid gains in fattening hogs as corn and tankage, in experiments at the Indiana station. The addition of a self-fed mineral mixture to corn and soy beans, hogged off, increased the rate of gain and lowered the cost, in experiments at this station.

In a comparison of various forms of lime as mineral additions to a standard ration for pigs at the Minnesota station, marl appeared to be a suitable material for such use. In experiments at the Illinois station the use of various mineral substances for pigs receiving corn tankage and middlings, both in dry lot and on bluegrass pasture did not give results justifying their use. Feeding mineral supplements ad libitum to growing and fattening pigs on rations containing feeds high or fairly high in calcium, such as tankage or good pasture, showed little if any effect on rate or economy of gains.

Rough rice was found by the California station to be an unsatisfactory feed for hogs, but rice polish, rice bran, and brewers' rice, supplemented with some animal protein, were satisfactory. In experiments at the Texas station rice bran showed a money value only 57 per cent as great as corn for pigs during the growing period but 70 per cent as great during the fattening period, measured by the amount of feed required to make a pound of gain. As compared with corn, rice bran invariably lowered the average daily gain and increased the quantity of feed required per unit of gain. The rice bran produced soft pork when fed for 150 days.

Hogs fed on soy bean forage with 2 per cent corn for 71 days produced soft pork, in experiments at the South Carolina station. In preliminary tests at the Georgia station the feeding of velvet beans to hogs showed a softening effect on the pork. In experiments at the Mississippi station, however, no such effect was noted.

In grazing experiments at the Mississippi station in which soy beans and corn were grown together, it was found to be usually most economical to gather the corn and graze the beans, hand feeding the corn in quantities up to 2.5 per cent of the live weight of the hogs.

Garbage alone did not prove to be as economical as garbage supplemented with barley as a feed for growing pigs, in experiments at the Wyoming station.

White and yellow corn appeared to be of equal feeding value for mature hogs, in experiments at the Illinois station, but young growing pigs did not do well on a ration of white corn and tankage, although those on yellow corn and tankage made normal growth. In winter feeding experiments at the West Virginia station yellow corn proved superior to white.

In a comparison of fish meal, tankage, oil cake, and oil meal with corn, at the Pennsylvania station, pigs fed fish meal made the largest gain, and no undesirable results followed the use of fish meal as a feed for brood sows, the strength and quality of the litters being as good as in case of sows receiving tankage or oats and middlings. Fish meal also gave the best returns at the Florida station in a comparison of fish meal, tankage, and linseed meal.

Barley appeared to be more palatable and to give a little more rapid gain than rye in experiments at the Montana station. In experiments at the Kentucky station the best results were obtained with whole barley soaked 24 hours with the addition of a self-fed mineral mixture. Grinding barley increased its value from 7 to 10 per cent in experiments at the Oklahoma station. Soaking lessened its feed value. There was a slight advantage in feeding whole or ground barley in the self-feeder. One part of tankage to 12 or 13 parts of barley appeared to be the best proportion.

Poultry.—Most of the stations are engaged in some line of poultry investigation. More than 170 projects were reported as active during the year. Among the investigations of special interest reported upon were those dealing with the effect of inbreeding; breeding for egg production, fertility, and hatchability; effect of time of hatching, feeding, and molting on egg production; effect of light, vitamins, and mineral matter. The progress of the breeding work is reviewed in the special article beginning on page 67.

Leghorn chicks hatched in April gave the highest egg production in 3-year records at the Utah station, while the lowest record was made by chicks hatched in March. The Missouri station found that the average length of time required to mature White Leghorn pullets, from hatching to date of first egg, was 232 days. Those which matured in less than the average time were superior in production, down to a maturing time of less than 200 days. The West Virginia station found that the younger the pullets when beginning to lay the smaller were the first eggs laid. The maximum egg production was reached in April or May. Pullet eggs increased in weight from the beginning to the end of the first laying period. In case of yearling hens the lightest eggs were laid during the summer months.

Slow molt and low egg production were found by the Iowa station to be closely correlated. When the ration was deficient in animal protein the molt was earlier than when a full protein ration was fed. The Utah station found that pullets maturing in less than 200 days laid during the early fall and then went into a winter molt which greatly handicapped their egg record for the year following.

Several of the stations have shown the advantage of animal protein and milk and milk products in the ration for laying hens. The West Virginia station noted that chicks which received a liberal quantity of protein of animal origin while young developed more rapidly and began to lay at an earlier age than those receiving a limited protein ration. The Minnesota station reports that without animal food or with only a small quantity, the mortality of White Leghorn chicks was very heavy and the gains in weight insignificant. The Pennsylvania station found that hens receiving a milk product in addition to a standard ration produced more eggs but at a higher cost than those receiving meat scraps and vegetable proteins plus a mineral mixture. The Idaho station in a comparison of various animal and vegetable protein supplements found that a ration containing pea meal and sour milk gave exceptionally good results in stimulating egg production and reducing the cost.

Artificial illumination was of no practical advantage as measured by the yearly egg production in experiments at the Pennsylvania station.

On the other hand, the Iowa station reports that where lights were used during January and February in the breeding pens from late afternoon to 7 p. m. egg production was stimulated, fertility and hatchability were not lowered, and a larger number of early hatched chicks was obtained. At the Kansas station exposing White Leghorn pullets to ultra-violet light for 10 minutes twice a day increased egg production and the hatchability of the eggs.

Polyneuritis developed in experiments at the Indiana station in cockerels fed degerminated corn for three weeks, but the birds were restored to health by feeding corn germs for one week. It was found that birds fed a high protein diet required a greater amount of vitamin B to protect them against polyneuritis than those fed on a low protein diet.

Twice as many eggs were obtained at the Kentucky station from hens fed a diet of corn and buttermilk with limestone as from those fed corn and grain tankage mash with limestone or corn and buttermilk without limestone. There was also a distinct increase in size of egg and thickness of shell. The calcium in rock phosphate appeared to be used by the hen for the production of bone but not in the formation of eggshell, while that in calcium carbonate was used for both purposes. Deficiency of calcium in the diet retarded the development of bone. The omission of grit from the diet of hens in confinement during the first eight months of their laying period did not affect either their egg production or physical condition.

In a series of incubation experiments the Indiana station found that a temperature of 101° F. throughout the period of incubation gave the best hatching results. White eggs pipped and hatched a few hours earlier than brown at the same temperature and consistently gave better hatches. Temperatures below the optimum of 100 to 103° delayed hatching and temperatures above this hastened hatching with a large number of undesirable chicks. The temperature of incubation showed a positive relation to the total number of dead embryos during incubation. The individuality of the hen appears to have an influence on the hatching of eggs at any temperature.

DAIRYING

Investigations in dairying cover a wide range in breeding, feeding, and care of dairy animals and the handling of milk and milk products.

Comparison of feeds.—A number of stations have investigated the value of soy bean hay for milk production. At the Pennsylvania station it proved slightly inferior to alfalfa hay for milk production. At the West Virginia station results of comparative tests were inconclusive. The South Dakota station found even inferior soy bean hay equal to alfalfa hay for milk production. At the Illinois station soy bean hay was found to be equal to alfalfa hay on the basis of hay actually consumed. This station found soy bean oil meal to be very palatable and to exert no undesirable physiological effects. It compared favorably with choice cottonseed meal as a protein concentrate for milk production. In tests at the Maryland station with soy bean hay to balance a dairy ration and as a substitute for wheat bran, the bran ration produced more milk and butterfat but the cost of the product was less with the soy bean hay ration.

Velvet beans gave good results in experiments at the South Carolina station when fed to dairy cows up to 50 per cent of a palatable grain mixture.

The use of corn fodder instead of corn silage reduced milk production 6 per cent and fat production 3 per cent, in experiments at the Iowa station. The Utah station found 2½ to 3 tons of corn silage equal to 1 ton of alfalfa hay for milk production. The vitamin C content of milk from cows fed silage was found by the South Dakota station to be much greater than that of milk from cows which were not fed silage. Sunflower silage proved to be cheaper and no less effective than oat and pea silage as a ration for milch cows in experiments at the Montana station.

Cows on a subnormal ration at the Missouri station showed a decided increase in the percentage of fat in the milk produced, the peak of the increase being reached about the end of the third day and remaining abnormally high for the 10 days the reduced ration was continued. When the ration was brought back to normal the percentage of fat decreased and remained below normal for the succeeding 10-day period. The quantity of milk was reduced, depending upon the length of the feed reduction period and the stage of the lactation period. The total yield of fat was not significantly changed.

The speed of milk secretion in unit time was found by the Missouri station to be governed by the amount of milk accumulated in the udder, or the interval between milkings. Taking the amount of milk secreted during the first hour as 100 per cent, the amount secreted each succeeding hour was approximately 95 per cent of that secreted during the preceding hour. The data indicate that the percentage of fat and total solids gradually decreased with the length of the interval between milkings, until the time interval exceeds 14 to 16 hours, thereafter slightly increasing up to the twenty-fourth to twenty-sixth hour, followed again by a gradual decline to the thirty-sixth hour.

Preservation of milk.—Milk charged with carbon dioxide under a pressure of 180 pounds at 40° F. was found by the Illinois station to keep sweet for 32 days and was practically sterile at the end of the storage period, even though its initial bacterial content was 100,000 per cubic centimeter. Physical changes, however, took place which affected the quality of the milk.

The storage temperature for bottled milk should be as close to freezing as possible (33° to 35° F.) in order to get the deepest cream line, according to results at the Pennsylvania station. The deepest cream layer appeared at the end of two hours when the samples were stored at 35°, after which time the cream layer contracted. Clarification and pumping of cold milk reduced the cream layer slightly, but pumping hot Pasteurized milk did not reduce the layer. Pasteurizing milk in a glass-lined vat at 144° to 145° for 30 minutes, followed by rapid cooling over a surface cooler caused a noticeable reduction of the cream line. It was found that evaporation by air blast or vacuum methods did not reduce the vitamin B content appreciably. After sterilization of the evaporated milk the destructive effect was more marked, particularly in sterilized milk made by the air blast method.

Rate of growth of heifers.—The amount of growth of heifers during a given unit of time at any age tends, according to the Missouri station, to be a constant percentage of the growth made during the preceding unit of time. Thus the growth in height at withers during any year is about 34 per cent of the growth made during the preceding year, and the growth in weight is about 56 per cent of that of the preceding year.

Flavors in milk and milk products.—Iron bacteria were found by the California station in about 25 per cent of the milk and butter of the State, and there was evidence that off flavors can be ascribed to their presence. In experiments at the New York Cornell station butter made from neutralized pasteurized cream had a better flavor than that made from the same cream unneutralized, whether raw or pasteurized. The butter made from neutralized cream did not keep much better than that from unneutralized, although the storage temperature in this case was relatively high (50° F.). The Wisconsin station found that the conditions which favor the development of fishiness in butter are high acidity of the cream, high salt content of the butter, overworking of the butter, and the presence of iron or copper salts. It was also found that lecithin in butter undergoes a purely chemical decomposition at room or incubation temperatures, yielding trimethylamine, the cause of fishy flavor. Trimethylamine was isolated from samples of fishy butter examined. An organism, *Bacterium ichthyosmius*, isolated from cream produced trimethylamine from lecithin under favorable conditions but not in the presence of salt and under acid conditions. It is believed to be unlikely that these bacteria cause fishiness, but that this is due to the chemical decomposition of lecithin normally present in butter. Pasteurization tended to eliminate fishiness.

Cheese of better flavor was obtained from clarified milk than from unclarified, in experiments at the Utah station. The same result was obtained by the Pennsylvania station, except where milk of poor quality was handled under ordinary creamery conditions.

Ice cream.—Low acid mixes (0.15 to 0.2 per cent) for ice cream gave a better flavored and better bodied product than high, in experiments at the Illinois station. The use of dehydrated egg yolks in the mix improved the texture and resistance of ice cream but imparted a pronounced egg flavor. The kind of milk products used in the mix affected the texture and flavor of ice cream. Homogenization improved the body of ice cream, increased the amount of overrun obtainable, and yielded a good ice cream with less milk solids. The percentage of overrun obtained had a marked effect upon the quality of the ice cream. The Pennsylvania station

found no relation between acidity at time of freezing and quality of the finished ice cream, but there was a relation between acidity of the mix and the melting properties of the finished cream. The bacterial content of the mix appeared to bear no relation to the quality of the cream. The Minnesota station found that the viscosity of ice cream mixes increased when held at low temperatures. When the mix was aged at 40° F. there was no increase in acidity.

VETERINARY SCIENCE

Investigation of animal diseases is one of the major lines of station work. A wide range of diseases of general as well as local importance has been investigated. Of the 5,000 or more research projects reported as active during the year, 193 related to animal diseases (including plant poisoning, especially on the ranges). Among the diseases upon which particularly significant work was reported were infectious abortion, tuberculosis, anthrax, hemorrhagic disease (icterohemoglobinuria), and botulism. Plant poisoning also receives much attention.

Infectious abortion is a widespread menace to farm livestock. Several stations are studying it with varying degrees of success. Means of transmission and effective control have been particularly baffling.

The California, Connecticut Storrs, Kentucky, Illinois, Michigan, Minnesota, Missouri, and Montana stations have made important recent contributions to the subject, especially along the lines of the chronic character of the disease and its transmission by carriers, vaccinated animals, and through milk and otherwise, the varying virulence of different strains of the causal organism, immunity of offspring of infected mothers, immunizing value of live abortion vaccines, transmission of the disease from cattle to swine, and other causes of abortion besides *Bacillus abortus*.

Several of the stations have demonstrated that animals once infected with abortion may remain carriers of the disease for an indefinite period. Moreover, as the California station has shown, vaccinated animals may become spreaders of the disease and can not therefore with safety be kept in uninfected herds.

In tests made by the Connecticut Storrs station calves were negative when born, but within a few hours after nursing positive cows became positive. However, they became negative by the time they were 5 or 6 months of age and remained so until they received a new infection from without. The California station found that it is not necessary to protect calves from infection through the medium of milk during the milk-drinking stage, but that they must be protected after breeding age, prior to and following breeding, to prevent abortion in the first pregnancy. The Michigan station found it improbable that *B. abortus* persists in the tissue of new-born calves from a prenatal infection or through injection of milk containing *B. abortus*. There was no evidence to show that calves from infected cows were more susceptible to calves' diseases or that breeding efficiency was impaired.

The California and Minnesota stations found live abortion vaccine to have some immunizing value in bovine abortion. The Michigan station used a nonvirulent living culture of *B. abortus* with very satisfactory results in immunizing cattle which were not already infected with the disease. The Illinois station obtained like results with such vaccine in case of swine abortion.

The Michigan station reports that swine possess a high degree of natural resistance to infection by *B. abortus* and that the feeding of infected milk or association with infected cattle is not dangerous so far as the possibility of infecting swine is concerned.

The Connecticut Storrs station observed wide variations in the virulence of different strains of *B. abortus* but no marked differences in morphology and cultural characters.

Eradication of the disease from a herd has been found to be a slow and somewhat uncertain process. The Connecticut Storrs station reports the elimination of the disease from a herd in seven years by promptly disposing of aborters and gradually eliminating old reacting cows. The Missouri station is using a similar method with some success.

The Montana station reports a study of abortion in sheep due to a Spirillum or Vibrio in contaminated drinking water, which caused losses of as high as 75 per cent of the lambs of affected range flocks. The station has devised a simple blood test whereby blood from aborting ewes can be distinguished.

Tuberculosis.—Much of the recent work of the stations on tuberculosis has dealt with the avian form of this disease. The Ilinois, North Dakota, and Wyoming stations find that avian

tuberculosis is readily transmitted to swine by injection and orally. An examination of a large number of cases of swine tuberculosis by the Nebraska station showed that 88.4 per cent was of the avian type. The Wyoming station by injection of cultures of avian tuberculosis in calves produced the so-called skin form of the disease which, however, could be removed and apparently cured by surgical operation. The Minnesota station failed to find positive evidence of turbercle bacilli in eggs of tuberculous fowls.

Anthrax.—The high virulence and viability of the anthrax organism has received further confirmation by investigations at the Louisiana station. This station found that the organism retained its virulence for three years in a soil alternately moistened and dried. *Tabanus fulvulus* was found to be an active carrier of the disease. Evidence was secured that the disease can be controlled by immunization.

In case of the obscure and baffling hemorrhagic disease known as icterohemoglobinuria which has been responsible for considerable losses of livestock, the Nevada station has successfully isolated the causal organism and succeeded in cultivating it and producing a serum of high curative potency. These results promise much from the standpoint of effective control of the disease.

Botulism has caused much alarm from the standpoint of its deadly effect on domestic animals as well as on man. The Illinois station has shown the varying effects of several types of avian botulism, and the Colorado station has reported the wide distribution of *B. botulinus* in virgin and cultivated soils.

Plant poisoning.—Among the poisonous or supposedly poisonous plants recently reported upon are saltbush (*Atriplex canescens* and *Artemisia spinescens*), chokecherry (*Prunus demissa*), low larkspur (*Delphinium andersonii*), and spring rabbit brush (*Tetradymia glabrata*) by the Nevada station; *Drymaria glauca* by the New Mexico station; and white snakeroot (*Eupatorium urticæfolium*) by the Indiana station. Saltbush as an exclusive feed caused sheep to abort. The chokecherry was found to be highly poisonous to sheep and cattle in the early summer. The low larkspur was found to be poisonous to cattle but not to sheep. The plant was found to contain 1.75 per cent of alkaloid calculated as delphinin ($C_{31}H_{49}O_7N$). Hungry sheep sometimes eat enough of the tender growth of rabbit brush in the spring to kill them. The poisonous property has not been determined nor a remedy found. *D. glauca* is a little known plant of limited habitat, known to be poisonous to cattle in New Mexico. The Indiana station found all farm animals susceptible to white snakeroot poisoning.

AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

Cost of production and farm organization.—The California station in a study of the business of 246 dairies in 11 dairying sections of the State for the year ended March 1, 1923, found that the cost per 100 pounds of whole milk ranged from $2.23 in the Kern district to $3.73 in the Los Angeles-Orange district, and that per pound of butterfat from 50 to 97 cents for the same districts. The New York Cornell station found the net cow cost of producing 100 pounds of milk on 83 farms in Chenango County to have been $2.73 and the herd cost $2.81. A loss of 69 cents per 100 pounds of milk sold is recorded, and after all charges except labor were met a return of 3.2 cents per hour for all the time spent on the enterprise.

In a study of the cost of producing apples in Minnesota from 1916 to 1920, an average gross return per acre of $215.99, ranging from $23.75 to $506.81, was shown by the station on the basis of 135.8 bushels of packed apples at $1.53 per bushel, 2 bushels used at home at the same price, and 12 bushels of culls at 43 cents a bushel. Comparing the profits from an apple orchard in the State for two 10-year periods, 1904–1913 and 1914–1923, the New York State station found the annual cost of tillage in the first decade to have been $7.39 per acre and in the second $14.40. The cost per barrel amounted to 6.6 and 11.7 cents, respectively. The average net profit per acre in the first decade was $95.60 and in the second $145.83.

The total cost per average litter of 5.5 pigs was found by the Oregon station to be $31.28, the final cost of growing a pig from weaning to maturity or from 30 to 200 pounds live weight, $12.85, and the total cost of a 200-pound pig, $18.54. The Missouri station found that 1.71 hours of man labor and 0.11 hour of horse labor were required to care for the average farm hen for one year. The average cost of keeping poultry through 11 years was $1.18 and the total income $1.67 per hen per year.

In a study of the amounts and distribution of labor and materials used in the production of different crops and classes of livestock, conducted by the Minnesota station in Cottonwood and Jackson Counties by the complete cost route method, it was brought out that on 22 of the 65 farms under study the miscellaneous work about the farm consumed from 5.2 to 25.1 per cent of the total man labor expended and from 2 to 15.9 per cent of the total horse labor. The Wisconsin station found that on 262 farms in Walworth County 80 per cent of the income was derived from dairying. The average labor income for the year ended May, 1921, was —$595. The labor incomes on the successful farms ranged from $318 for farms of less than 60 acres to $819 for those of more than 180 acres. Farms having five or more sources of income had an average farm income of $1,504. Dairy herds averaging more than 7,000 pounds of milk per cow produced at a cost of 40 cents per hundredweight less than herds producing between 5,000 and 7,000 pounds and $1.19 less than herds whose production did not exceed 5,000 pounds per cow.

A study by the Kentucky station of 241 farms in Mason and Fleming Counties for the farm year 1922 indicated that the average farmer made a labor income of $1,029, while the best 15 farmers earned an average of $3,203. The average total receipts were $3,714 per farm and for the best 15 farms $7,124. The average value of the perquisites furnished by the farm for the living of the operator's family was $332 per farm and for the best 15 farms $422.

A study made by the New York Cornell station in dairy sections of Chenango, Broome, and Delaware Counties showed that the average annual cost of operating a truck, exclusive of the cost of a driver, in the year ended September, 1921 was $395. The average cost per mile for second-hand trucks was 8.3 cents, as compared with 11.8 cents for 41 which were bought new. The average cost per ton-mile of hauling, less the expense of the driver, was 16.2 cents by truck and 25.7 cents with horses and wagons, while the cost of a driver for horses added 14.6 cents, as compared with 5.3 cents for trucks. The introduction of trucks into these dairy sections is held to have extended the market milk territory farther back into the hill country.

Marketing.—A study by the Ohio station of cooperative livestock shipping associations in eight counties of the State brought out a wide divergence in the weights and prices at which livestock is marketed in different counties in the State. The total expense of marketing each 200 pounds of hogs sold in 1922 ranged from $1.01 to $1.63, averaging $1.29. The net return to the farmer ranged from $18.07 to $19.17 and averaged $18.61.

A study by the Kansas station indicated that in general the milk supply of six representative cities in the State came from near-by farms. More adequate inspection and grading and more efficient methods of delivery were deemed advisable. The Pennsylvania station found that Altoona offered an active market for locally produced eggs and poultry of good quality and that 8 per cent of the potatoes, a large part of the vegetables, all of the raspberries, 69 per cent of the apples, and 7 per cent of the grapes used were produced locally.

Land tenure.—In a survey made in 1920 the Nebraska station found tenancy to be increasing rapidly when measured by acreages, farm values, or the number of farms, although two-fifths of the farms studied were not rented at all during the decade preceding the survey and one-third of the farmers of all tenures had been on the same farms for more than 10 years. The Iowa station in a study made in Cedar County found that 59.2 per cent of the farms were operated by owners and owners who rented some additional land. The percentage of owner farms had decreased from 72 in 1910 to 62 in 1919, while tenant-operated farms had increased from 28 per cent in 1910 to 38 per cent in 1919 and to 40.8 per cent in 1920.

Detailed intensive studies and field surveys made by the California station in selected districts in the State indicated that fruit properties when leased, which was said to be in exceptional cases, were usually closely supervised and such leases followed a fairly uniform type. Dairies or lands for dairying purposes were leased by both cash and share methods, as was also land for truck crops. Very little leasing of poultry farms was practiced. The majority of ranges and livestock ranches were leased for cash.

Land valuation and taxation.—From a statistical study made in Brazos, Williamson, and Dallas Counties, the Texas station showed that the ratio of share rent to land value fell with a drop in prices or poor crop, and conversely that when there was a

tendency for share rental to rise through a series of years land values very soon rose and the ratio of rents to land values diminished even though the value of share rent continued to rise. The lowest rate of return was found on the best land for the reason that here the tendency was for rents to rise most rapidly, and as a result the landlord had capitalized future increases as well as the rent.

Records of sales of real estate in the State were analyzed by the Kansas station, the conclusion reached being that small properties are overassessed. The inequality in the assessment of farm real estate, taking the counties as taxing units, has decreased during the last 10 years, however. The inequality in the rate of assessment among individual parcels of farm real estate is held to be nearly 14 times as important as inequalities in the assessment of farm real estate, taking the county as a whole as the unit, from the standpoint of the amount of taxes levied on overassessed properties in excess of legal requirements.

Rural community organization and farm life.—Out of 150 answers to a questionnaire sent out by the New York Cornell station in Otsego County, 26 indicated that the neighborhoods which they represented had no school or that the school was closed, and 95 reported no community use being made of the school. Of 122 schools for which reports were made, 3 or 4 indicated a definite effort to do more than regular school work. The Wisconsin station found that of 29 towns and villages in Dane County, exclusive of the city of Madison, 23 performed several fundamental economic and social services. Five types of services were found and eight types of service agencies were identified. In 11 small towns in this area there were found to be more agencies per total population in trades and repair, communication and transportation, finance, religious, and educational types than of personal, professional, and social organization activities.

Mapping country parishes and investigating the local history of rural religious organizations in Dane County, the Wisconsin station defined three streams of settlement from Europe and the eastern States corresponding to the major religious groups, including Lutheran, Roman Catholic, and Reformed Churches. There was found to be a rough correspondence between the parish boundaries of churches located in villages and small towns and the trade areas of these various centers. Churches located in a trade center were as successful in reaching the farmers as were those in the open country.

A study by the New York Cornell station of the movement of farm population from 1,110 farms in four counties in New York showed that from 1917 to 1920 men and boys were leaving at about two and one-half times the rate at which they were being produced. The rate had changed from 12 per cent for those born between 1830 and 1839 to 56 per cent for those born between 1890 and 1899. The rate for women changed in the same time from 12 to 60 per cent. Out of 699 Livingston County farmers, on the average the men who stayed on their fathers' farms had profited financially and those who had always been on farms were better off than those who had tried some other occupation for a year or more.

From a survey by the same station of certain townships of Livington County, the correlation between size of business as measured by acres, capital, and work units and the standard of living was calculated to be about 0.4. Living conditions in tenant homes compared very favorably with those in owner homes. Approximately half of the families giving the larger amounts for church support appeared to be enjoying relatively high living standards. Parents with the higher education were found to be enjoying relatively higher standards and employing more capital and labor. The Missouri station found that the cost of family living did not vary as farm labor incomes but followed more closely the trend of retail prices. The value of products furnished by the farm was one-fifth of the total living cost.

AGRICULTURAL ENGINEERING

Tillage machinery.—The Missouri station obtained an average plow draft of 5.04 pounds per square inch of furrow slice in corn stubble in 150 tests. Soil moisture content was found by the Nebraska station to be the most difficult factor, affecting plow draft, to control. It has a rather pronounced effect upon draft, chiefly because of its influence on the compactness and shearing strength of soils. At low compactions of the soil the plow draft decreases slightly with an increase in moisture content up to about 17 per cent. As the moisture increases from this point the draft increases slightly. It also increases

uniformly with an increase in the degree of compactness, this increase being about 80 per cent between compactions corresponding to volume weights of from 64 to 76 pounds per cubic foot of soil.

In dry sandy soil having a negative value of the spreading coefficient of the soil solution and a bearing power less than the pressure imposed, the Alabama station found that the coefficient of sliding friction of chilled plow iron with a polished surface varies with the speed of passage, is proportional to the pressure per unit area, and varies with the smoothness of the metal surface and the materials composing it. When the bearing power of the soil is greater than the pressure imposed per unit area and the value of the spreading coefficient of the soil solution is negative, the magnitude of the friction is proportional to the total pressure between the two surfaces, and the coefficient of friction depends upon the roughness of and the materials composing the metal surface and is independent of the area of contact and the speed of sliding. When there is enough moisture present to cause the soil to adhere to the metal surface but not to leave any moisture thereon, the coefficient of friction varies with the speed, the area of contact, the pressure per unit area, the surface and kind of metal, and the surface tension of the soil moisture film. In these circumstances the friction coefficient therefore also varies with the content of colloidal matter and moisture in the soil, and with the temperature and viscosity of the soil solution. When there is sufficient moisture present in the soil to produce a lubricating effect, the coefficient of friction varies with the pressure per unit area, the speed, the amount of moisture present, and the viscosity of the soil solution. The indication is that the coefficient of sliding friction of metal in soils is a dynamic and constantly varying factor and is governed in any soil chiefly by the moisture content and the size of soil particles.

Tractors.—The California station showed that by plotting a curve between the quantities of dust caught on the several cloths of an absolute air cleaner for a tractor motor and the number of cloths, it was possible to determine the additional quantity that would have been caught if a definite number of cloths were used. It was thus possible to determine the composition of an absolute cleaner. It was also found that every air cleaner built can be made to test 100 per cent efficient if a shrewd choice is made of the dust to be fed into it. The particles must be large enough so that they can not pass the filter and must be heavy enough so that inertia or gravity will leave them behind when the air going toward the carburetor swings around a turn. It was further found that the quantity of dust inspired by any cleaner or carburetor is greatly reduced if the intake is placed high and faces away from the direction of motion of the tractor.

Wagon draft.—The results of 164 tests at the Missouri station checked closely with the rule that the draft of wagons, under various road and field conditions and with different sizes of wheels and widths of tires, varies directly with the load and inversely with the radius of the wheel than with rules using the square root or the cube root of the radius. Wide tires decreased the draft. Coefficients of rolling friction of 0.508 for worn brick pavement, 0.366 for new brick pavement, 0.417 for concrete pavement, 1.814 for dry dirt road, 1.98 for muddy dirt road, 0.565 for gravel road, and 0.755 for cinder road were established.

Silage cutters.—The Wisconsin station showed that available silage cutters have much greater capacities than is ordinarily assumed and that 15- or 16-inch flywheel machines and 18- or 20-inch cylinder machines have much more capacity at present rated speeds than any ordinary crew of men can supply, proving that larger machines are unnecessary. Such machines could be operated at speeds approximately 40 per cent slower than recommended speeds and still have sufficient capacity for ordinary requirements, thus resulting in much greater efficiency. The real capacity of the silage cutter was found to be proportional to its speed. It was proved that at slow speeds high efficiency can be obtained, the quality of cutting is excellent if the knives are set quite close, wear and tear is less, and a machine can be designed to elevate properly. In most cases the efficiency was affected but little by moderate variations in the capacity, with a slight tendency toward better efficiency with higher capacity.

Marl excavating equipment.—The Michigan station showed that pumping is the most successful process for marl excavation from the mechanical standpoint, but involves a considerable investment and overhead cost for operating. A special agitator was developed consisting of a rotating propeller-like cutter surrounded by a large

hood attached to the end of the suction pipe. This hood was allowed to sink into the marl, which was agitated, mixed with water, and pumped. Where a large investment for equipment in large sizes is permissible, the slack-line-cableway excavator is permissible, although generally not economically installed. It was found necessary with this equipment to control the depth to which the excavator bucket cuts and to employ mechanical means for emptying the bucket of the sticky material.

Drainage.—The Minnesota station found that the downward penetration of corn roots in peat soils is bounded by a zone sharply defined by the flattening out of the roots within it. This zone is not more than 3 inches thick and is not at or near the water table. Its underside, beyond which the roots do not penetrate, is approximately 18 inches above and parallel to the water table. These results have an important bearing on the design of drainage systems to control the water level in marsh soils.

Duty of water in irrigation.—The Utah station found that where water is available at a given price the economical number of acre-inches of water to apply per acre is independent of the cost of plowing, seeding, fertilizing, etc., since this cost is not a function of the ratio of the cost of water per acre-inch to the price per ton of the crop on the farm. The maximum profit per acre will be obtained with some quantity of water less than the amount necessary to obtain the maximum yield. Where a large area of land is available, but the water supply is limited, and it is desired under these circumstances to obtain the maximum profit for the entire area, the price of the water does not influence the quantity of water for each acre which will bring such maximum profit. However, if the most economical quantity of water is used on each acre, the total profits decrease as the cost of the water increases, and vice versa. Increasing the cost of ditching and application of water is equivalent to increasing the cost of plowing, seeding, fertilizing, etc. This indicates that it will pay better to use more water per acre than to spread it over a large area by the use of more ditches and labor.

Alkali soils.—The New Mexico station showed that the use of aluminum sulphate even in small percentages increased the permeability of irrigated soils sufficiently to indicate that small areas of such soil may be profitably improved by this treatment. As much as 2 per cent of aluminum sulphate could be added to alkali soils with a high content of calcium carbonate without toxic effects.

Biology of sewage disposal.—The New Jersey stations showed that the bulk of the downflowing sewage does not filter through the film around the stones of a sprinkling filter. Solutions of certain chemicals of many times the concentration necessary to kill protozoa exposed directly to them had no effect on the protozoa in the film during the period of a normal spray on the beds. The largest numbers of either reducing or oxidizing bacteria per cubic centimeter were found in the digestive chamber of the Imhoff tank of a sewage treatment plant. The effluent from the sprinkling filter normally contained the fewest bacteria per cubic centimeter. The organisms most important numerically throughout the plant were the nitrate reducers, hydrogen sulphide producers, and the albumin digesters. Nitrifying and sulphur-oxidizing bacteria occurred throughout the plant and were consistently found even in the digestion chamber of the Imhoff tank. The numbers of nitrifying bacteria increased in the filter bed, although they never became numerically predominant, and they occurred in higher percentages in liquid which had trickled through the lower levels of the bed than in that collected near the surface. The numbers of hydrogen-sulphide producing organisms decreased as the sewage passed through the plant. A higher nitrate production was found to occur in the lower than in the upper levels of a sprinkling filter.

Draintile.—The Minnesota station showed that concrete tile for use in peat soils should be steam cured and should have an absorption of less than 7 per cent of the dry weight and a breaking strength of not less than 1,600 pounds per linear foot for all 30-day-old tile up to 16 inches in diameter, with an increase of 100 pounds for each inch in diameter thereafter. A strength two-thirds as great as this is permissible for concrete tile laid in a clay subsoil and for shale tile in any soil for all depths down to 6 feet. At greater depths the greater strength is required for both shale and concrete tile.

Soil erosion.—The Missouri station showed that deep plowing (8 inches) is only slightly more effective than shallow plowing (4 inches) in preventing run-off and erosion. A growing crop, particularly small grain or sod, furnishes the most effective means of reducing erosion.

PRESENT STATUS OF HOME ECONOMICS RESEARCH AT THE AGRICULTURAL EXPERIMENT STATIONS

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SCOPE OF SURVEY

This paper represents an attempt to scertain the present status of home conomics research in the agricultural xperiment stations,[1] as distinct from hat of the land-grant colleges as a vhole, a survey of which was reported t the 1924 meeting of the Association f Land-Grant Colleges.[2] The sources f information in the present survey vere in all cases the reports received n reply to a circular letter sent in 924 to the director of each station, equesting a complete list of research rojects under active investigation.

In selecting from the long lists of rojects submitted those of possible earing on home economics, the folowing definition of home economics esearch proposed by the committee vhich made the survey of home ecoomics research in the land-grant colleges referred to above has been kept n mind:

> Research in home economics includes all udy by the experimental method (namely, e assembling of observations and facts nder conditions which permit a cause and fect interpretation and deduction thererom of principles which form the basis of nowledge) of all the phenomena and facrs which are involved in home life, and f the problems growing out of homes and eir interrelationships.

In classifying the projects selected, e four main divisions under which e work of the Bureau of Home Ecoomics of the Department of Agriculre is being conducted have been sed. These are: (1) Food and nuition, (2) clothing and textiles, (3) conomic and social, and (4) household equipment. The accompanying tabulation thus indicates in a general way the stations most actively engaged in work pertaining to home economics, the research departments of the stations in which work related to home economics is being carried on, and the phases of home economics research at present receiving special attention.

As far as could be judged by the statements of projects, 17 of the 50 stations included in the survey[3] are not engaged in any research which has direct application to home economics, and only 4 of the stations report research projects conducted in home economics departments as such. On the other hand, the list of departments whose research projects appear to have a bearing on some phase of home economics as summarized below is encouraging and furnishes an excellent verification of the statement made by Dr. R. W. Thatcher in his paper on The Field of Research in Home Economics at the 1924 meeting of the Association of Land-Grant Colleges[4] to the effect that—

> There are many fine projects of research which are being carried on in departments of chemistry, physiology, bacteriology, economics, sociology, etc., which have a very definite application to the problems of home life. These are as truly research in home economics as if they were organized, administered, and prosecuted by members of home economics staffs.

The list is perhaps not complete, but it shows a total of 130 projects at 33 stations carried on in 14 different departments, as follows:

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[1] For an editorial review of the subject, see Experiment Station Record, 40 (1922), . 601.

[2] Assoc. Land-Grant Cols. Proc., 1924, p. 399.

[3] The stations in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands are not cluded.

[4] Assoc. Land-Grant Cols. Proc., 1924, p. 393.

Experiment Station projects of application to home economics, 1924

Station	Station department conducting the research	Phase of home economics concerned	Title of project
Alabama	Animal industry	Food and nutrition	The vitamin content of certain nuts.
Do	Agricultural engineering.	Household equipment.	Requirement for farm refrigeration outfits. Temperature and impact requirements of dish-washing machines.
Arkansas	Agricultural chemistry.	Food and nutrition	Dietary requirements for reproduction. Cause of inadequacy of milk proteins for reproduction. Iron content of certain foods.
California	Dairy industry and fruit products.	do	Fruit in ice cream.
Do	Nutrition	do	Study of California foods and food products with respect to content of vitamin C.
Do	Pomology	do	Storage of fruits at low temperatures for preserving, canning, and soda-fountain use.
Do	Rural institutions	Economic and social	Study of economic and farming conditions in irrigated districts.
Do	Viticulture and fruit products.	Food and nutrition	Glacé fruit; miscellaneous fruit juices; grape sirup; packing dried fruit; moisture loss in dried fruit; preparation of merchantable products from surplus fruits; use of fruits in ice cream.
Colorado	Bacteriology	do	Heat-resisting bacteria in fresh and canned vegetables.
Do	Economics	Economic and social	Rural life studies
Do	Home economics	Food and nutrition	Cooking quality of Colorado potatoes. Bread-making qualities of Colorado flour.
Connecticut (State).	Analytical chemistry.	do	Analyses of diabetic foods.
Do	Biochemistry	do	Protein research and nutrition studies: (1) Proteins of green plants. (2) Relation of chemical constitution of diet to the development of rickets. (3) Studies of the relation of vitamins to nutrition. (4) Part played by proteins, carbohydrates, and fats in nutrition. (5) Effect on the eye of deficiency in fat-soluble vitamins. (6) Effect of diet on fertility. (7) Relation of chemical structure of the proteins to their nutritive value.
Connecticut (Storrs).	Agricultural economics.	Economic and social	Intensive economic studies in selected towns.
Delaware	Chemistry	Food and nutrition	Study of factors affecting jellying of fruits.
Idaho	Agricultural chemistry.	do	Iodine-content of Idaho-grown foods in relation to prevalence of goiter.
Do	Agricultural engineering.	Household equipment.	Design and installation of farm water systems.
Illinois	Animal husbandry.	Food and nutrition	The nutritive value of the proteins of feeding stuffs and the biological values of the proteins.
Do	do	do	The relation of light to nutrition (indirectly applicable).
Do	Dairy husbandry	do	Study of the preparation of fermented milk drinks and their value from a dietary and medicinal standpoint.
Indiana	Dairy	do	The manufacture, chemistry, and bacteriological study of ice cream. Study of the growth and development of rats fed with and without dairy products.
Do	Home economics	Food and nutrition and household equipment.	Studies in fuel consumption in the preparation of meals by the use of certain types of cookers.

Experiment Station projects of application to home economics, 1924—Contd.

Station	Station department conducting the research	Phase of home economics concerned	Title of project
Iowa	Agricultural economics and farm management.	Economic and social.	Farm organization studies.
Do	Animal husbandry.	Food and nutrition.	Meat investigations.
Do	Chemistry and pomology.	do	Chemical changes in the ripening and storage of apples.
Do	Dairy	do	Factors influencing the yield and consistency of ice cream.
Do	Rural sociology	Economic and social.	Farm cost of living and standard of living studies. Studies of villages and open country relationships.
Kansas	Chemistry	Food and nutrition	Studies of the chemical aspects of certain milling processes.
Do	Milling industry	do	Chemical and milling tests on wheat produced in various agronomic experiments and comparative chemical and milling behavior of Kanred and other wheat varieties.
Do	Dairy husbandry and bacteriology.	do	Bacterial, mechanical, and temperature factors in the manufacture and storage of ice cream.
Kentucky	Chemistry	do	To determine if manganese is an essential element in animal metabolism, with particular reference to vitamins.
Do	do	do	To determine if manganese, copper, and zinc are essential factors in reproduction and metabolism.
Do	Economics	Economic and social.	Investigation of cooperative marketing and purchasing among farmers of Kentucky. The farmers' standards of living.
Michigan	Agricultural engineering.	Household equipment.	Use of electricity on the farm.
Do	Bacteriology	Food and nutrition.	Microbiology of food of man and domestic animals.
Do	do	Clothing and textiles	Flax retting.
Do	Chemistry	Food and nutrition.	Analyses of Michigan wheat and flour.
Minnesota	Agricultural biochemistry.	do	Cereal and flour investigations (transferred to flour mill). Strength of wheat flour. Chemical and biological studies in animal nutrition. (1) Factors influencing the vitamin content of milk. (2) Factors influencing the stability of vitamins in human and animal foods. (3) Studies on the chemical nature of vitamins A and B. (4) Studies on the quantitative requirements of laboratory animals for vitamins. (5) Studies regarding the function of vitamins in the animal body. Chemistry of the formation and manufacture of dairy products and factors influencing milk production and the composition and properties of milk.
Do	Agricultural economics.	Economic and social.	The organization of farmers' supply service.
Do	Agricultural engineering.	Household equipment.	Investigations of farm buildings. Heating and ventilating of homes. Utilization of electricity.

Experiment Station projects of application to home economics, 1924—Contd.

Station	Station department conducting the research	Phase of home economics concerned	Title of project
Missouri	Agricultural chemistry.	Food and nutrition	Protein storage in protoplasmic tissue.
Do	Animal husbandry.	do	Relation of diet to bodily activity and the capacity to withstand unfavorable circumstances.
Do	Dairy husbandry	do	The effect of each ingredient on the manufacture of ice cream.
Do	Home economics	do	Psychology of child nutrition. Thrice-cooked vegetables for diabetics. A nutrition problem with special reference to negro children. The effect of external temperature upon basal metabolism under usual conditions of dress. Selection and economic use of soap in the home.
Do	do	Clothing and textiles.	Color knowledge essential to costume and its practical application.
Do	Rural life	Economic and social	Analyses of the Columbia trade area showing the influence of various economic factors on shape and size of the trade area. Standard of living on the farm as factor in cost of production. Movements of rural population in Missouri. A study of the rural primary groups of Boone County.
Montana	Agronomy	Food and nutrition	Composition and quality of Montana wheats. Influence of climate upon baking quality of hard wheats.
Do	Agronomy and chemistry.	do	Changes in wheat when frosted and their effect on baking quality.
Nebraska	Dairy	do	Studies of the principles of ice cream making.
Do	Chemistry	do	Relation of certain chemical and physical chemical characteristics of Nebraska wheat to its milling and baking quality.
Do	Dairy	do	Studies of fat-soluble A as present in milk of four dairy breeds.
New York (Cornell).	Home economics	do	An experimental study of the effect of various methods of canning carrots on their antiscorbutic properties. Experiments in feeding rats, using potatoes as basis of diet. Differences in antiscorbutic properties of yellow compared with red tomatoes. Differences in vitamin A content of yellow and green beans. Studies on the keeping qualities of certain foods in household refrigerators.
Do	Rural education	Economic and social	Problems of rural school attendance. Guidance resources of rural communities. Community activities in relation to teaching.
Do	Rural social organization.	do	Village population and service agencies. Study of rural social organizations. Influence of sickness and death on the economic and social status of the family.
New York (State).	Dairying	Food and nutrition	Investigations in the manufacture of ice cream.
Do	Bacteriology	do	Tomato products investigation (cause of gaseous fermentation).
North Dakota	Milling	do	Effect of variety, soil, climatic conditions, and disease upon milling and bread value and chemical composition of wheat. Effect of storage on milling and baking quality and chemical composition of wheat. Durum wheat investigations.
Oklahoma	Not stated	Economic and social	General economic and social investigations.
Oregon	Agricultural chemistry.	Food and nutrition	Specific rôle of the inorganic elements, potassium in particular.
Do	Horticulture	do	Dehydration of fruits and vegetables. Canning of Oregon-grown apples.
Pennsylvania	Chemistry	do	Influence of commercial condensing processes on vitamin content of cow's milk.
Do	Agricultural economics.	Economic and social	Marketing survey of food products in various counties in Pennsylvania.

Experiment Station projects of application to home economics, 1924—Contd.

Station	Station department conducting the research	Phase of home economics concerned	Title of project
South Dakota	Dairy	Food and nutrition	Influence of corn silage on the vitamin C potency of milk.
Texas	Animal industry	Clothing and textiles.	Determining the grades and shrinkages of Texas wool and mohair
Do	Farm and ranch economics.	Economic and social.	Survey and analysis of rural church conditions.
Utah	Human nutrition	Food and nutrition	Nutrition of infants. Relationship of breed and individuality of cows to curd characteristic of milk.
Do	Bacteriology and chemistry.	do	Changes in flour on storage.
Vermont	Animal husbandry.	do	Nutritive value of milk, its suitability for food for children and animals, conditions which affect its nutritive value, tolerance, and related questions. Work with small animals on protein and maintenance needs.
Do	Dairy husbandry	do	Acidity of ice cream mix.
Virginia	do	do	Comparison of food value of milk of different grades.
Do	Agricultural economics.	Economic and social.	Production, distribution, and marketing studies of food products for Roanoke city.
Washington	Chemistry	Food and nutrition	Nutritive value of wheat and wheat products.
West Virginia	Agricultural economics.	Economic and social.	Supply method of marketing and consumption of food in West Virginia cities and agricultural production in near-by territory.
Wisconsin	Agricultural bacteriology.	Food and nutrition	Factors concerned in coagulation of milk by heat.
Do	Agricultural biochemistry.	do	The effect of organic nutrients from single versus mixed plant sources on the growth and reproduction of animals. Studies of the factors necessary in the maintenance of mammals, as vitamins, light, etc. Sources of vitamins in feed; the relation of pigments to animal nutrition; the stability of vitamins and their relation to growth and reproduction.
Do	Agricultural economics.	Economic and social.	Country life investigations: (1) A study of towns and villages as social and economic service stations. (2) A detailed study of 7 Wisconsin small towns. (3) Rural religious organizations.
Do	Agricultural engineering.	Household equipment.	Availability of electric power on the farm.
Wyoming	Wool	Textiles and clothing.	Studies of fleece and wool characters.

Classification of projects by departments conducting the research

Department	Number of projects	Department	Number of projects
Chemistry, including agricultural and biological	35	Bacteriology	5
Agricultural economics and rural sociology	26	Milling	5
Home economics	14	Agronomy	3
Dairy husbandry	13	Horticulture	2
Animal husbandry	8	Nutrition	2
Agricultural engineering	8	Pomology	1
Viticulture and fruit products	7	Wool	1
		Total	130

As grouped by the appropriate divisions of the subject of home economics, food and nutrition leads with 91 projects, followed by economic and social 27, household equipment 9, and clothing and textiles 4. This proportion is about what would be expected and does not differ materially from the distribution of projects in the home economics departments of the land-grant colleges. The list of projects relating to food and nutrition might well have been enlarged to include the studies on mineral metabolism which are being conducted at the various stations and are yielding results of indirect application to human nutrition. It is difficult in specific cases to draw any fixed line between animal and human nutrition. In general the principles involved are the same.

Many of the problems of agricultural economics are intimately connected with the problems of the farm home, and there is great opportunity for cooperation between the departments of agricultural and home economics. The fields of research in household equipment and in clothing and textiles are practically unexplored. In the former, cooperation with departments of agricultural engineering is desirable; in the latter, strengthening of the textile divisions in the home economics departments and cooperation with departments interested in wool and cotton. No attempt will be made here to discuss the projects classified under any of the divisions except that of food and nutrition, but it seems worth while to note the general trend of the work in this field as judged by the statements of progress accompanying many of the project lists.

GENERAL STATUS OF RESEARCH WORK IN FOOD AND NUTRITION

Food analysis.—In several of the stations the inspection of food and drugs is a part of the work of the station chemist, but as this is of the nature of routine analytical work it has not been included in this report with the exception of one project at the Connecticut State station on the analysis of diabetic foods. This is of special interest in connection with the precautions that must be taken in the control of the diet in the insulin treatment of diabetes. Of interest in this connection is the project reported by the home economics department of the Missouri station on thrice-cooked vegetables for diabetics, the purpose of which is to determine the vitamin content of the thrice-cooked vegetables which are used so extensively in diabetic diets. Preliminary work has shown that thrice-cooked spinach is entirely inadequate as a source of vitamins.

Analyses of foods for various inorganic constituents form a part of certain projects as a preliminary step to the study of more fundamental questions, such as the importance in nutrition of individual elements occurring in food materials in minute amounts. As such, may be cited the study at the Arkansas station of the iron content of certain foods, and at the Idaho station of the iodine content of Idaho-grown foods in relation to the prevalence of goiter. The latter topic is one that might well engage the attention of home economics departments of institutions in localities where goiter is at all prevalent, since the direct relation between iodine deficiency in food and drinking water and the prevalence of goiter is now an established fact. Recent surveys, conducted for the most part by public health officials, have shown that in several States, including Ohio, Michigan, and Montana, goiter is sufficiently prevalent to warrant the iodine prophylaxis of school children.

Wheat and flour studies.—At the experiment stations in the wheat-growing States chemical studies of flours milled from different varieties of wheat and from the same variety subjected to different environmental conditions, and studies of the relation of the chemical composition of the flour to its bread-making qualities are important research projects. Active investigation along these lines is being conducted by such departments as agronomy, chemistry, and milling at the Kansas, Michigan, Minnesota, Montana, Nebraska, North Dakota, and Washington stations. The scope of these studies ranges from simple chemical analyses of wheats and flours with relation to their baking quality, to physicochemical studies of the factors involved in flour strength. In so far as these investigations lead to the selection of wheat for better bread-making qualities and to the improvement of flour of poor quality by the addition of certain ingredients or the alteration of the proportions of the usual ingredients to bring about optimal baking conditions, they may rightly be considered research in home economics. There is opportunity for the home economics department and cooperate in this work and to institute similar research of their own.

Utilization and preservation of food products.—A field in which there is opportunity for close cooperation between the home economics department and other research departments is the development of methods for the utilization of perishable food products such as fruits and vegetables. At the California station the departments of pomology and of viticulture and fruit products are conducting a number of projects dealing with the preservation and utilization of surplus fruits. At the Iowa station the departments of chemistry and pomology are studying the chemical changes in the ripening and storage of apples. At the Oregon station the horticultural department lists projects on the dehydration of fruit and vegetables and the canning of Oregon-grown apples. Similar studies are contemplated by the department of horticulture at the Illinois station. In all cases one of the most important aims is to preserve as far as possible the natural flavor of the original product. To judge whether this has been accomplished and to develop the most satisfactory methods of utilizing the products, the home economics departments should be the best qualified and their cooperation should be sought by the departments conducting the research. In general, the development of better methods of utilizing food materials of all kinds is an important phase of home economics research.

There is also opportunity for cooperation between the departments of home economics and bacteriology in connection with such projects as that reported by the Colorado station on heat-resisting bacteria in fresh and canned vegetables. Wherever *Bacillus botulinus* is prevalent particular attention should be paid to the development of safe conditions of canning. The essential principles involved are bacteriological and the successful canner should be familiar with the recent important developments in bacteriology concerning thermophiles, heat penetration in various media, the H-ion concentration favorable for the growth of various microorganisms, and like questions.

Another phase of investigation along the lines of fruit utilization and preservation is illustrated by the work at the Delaware station on factors affecting the jellying of fruits. This project, under investigation by the chemistry department, deals with the relationship between acidity, pectin, and sugar concentration in the jellying of fruits. As the result of these studies and of similar work at the California station and elsewhere, jelly making is being put under scientific control and is no longer a rule of thumb procedure. The application of these principles to local conditions and to the utilization of surplus fruits suggests possible projects for home economics departments in various parts of the country.

Milk and dairy products.—Listed in the foregoing tabulation are no less than 21 projects from 16 stations dealing in some way with milk or dairy products. Six of these projects are concerned with the manufacture of ice cream and have been listed here as possibly contributing some suggestions of value in the home preparation of ice cream; two deal with the preparation of fermented milk products; several are connected with vitamin studies to be discussed later; and one or two are chemical studies undertaken primarily in connection with the manufacture of condensed, evaporated, and dried milk. Progress in all of those projects will naturally be followed closely by home economics workers with a view to possible applications.

Two of the projects listed are of particular interest as regards infant feeding. One is the Vermont station project on the nutritive value and tolerance of milk and milk preparations, in which young pigs are being used as laboratory animals to indicate the nutritive value and tolerance by children of milk of different kinds and richness and of various milk preparations. The human nutrition department of the Utah station is conducting a project with the same purpose in view—a comparison of the milk from various cows in regard to digestibility and food value for infants, but is approaching the question from a different angle. On the theory that the digestibility of milk depends largely on the softness of the curd, a curd test was developed for determining curd variance in milk, and this test has been applied to milk from different cows of the same breed and of different breeds. The results thus far obtained indicate that the curd character varies with the individual and also with the breed. Moreover, infants have responded more favorably to milk with the softer than the harder curd. This suggests an interesting application in special milk for infant feeding.

Protein investigations.—The Utah station project outlined above is essentially a protein investigation. At the Missouri station the department of agricultural chemistry is conducting an investigation on protein storage in protoplasmic tissue, the results of which may be applicable to human as well as animal nutrition. A study at the Arkansas station of the cause of the inadequacy of milk proteins for reproduction has furnished evidence of the existence of a vitamin essential for reproduction. At the Illinois station the studies of Mitchell in the department of animal nutrition on the nutritive value of the proteins of feeding stuffs has been extended to the determination of the biological values of the proteins of foods commonly used in the human diet, and results have already been reported on the relative biological values of eggs, milk, and meat as compared with wheat, oats and corn. In the outline of the project as a whole, the statement is made that its purpose is to determine the protein requirements of farm animals and then, from the net protein values (percentage protein × percentage digestibility × biological value), the amount of different feeding stuffs required to furnish sufficient protein to meet these requirements. The further statement is made that "part of the purpose of the project is to help to define the precise value of animal products in human dietetics as compared with staple vegetable products." The application of this project to home economics is thus expressed in no uncertain terms.

At the Connecticut State station the fundamental research on proteins under the direction of Dr. T. B. Osborne is still continuing. Begun years ago as an investigation of the chemistry of plant proteins, and developed essentially as a study in animal nutrition, this work has contributed more to our present knowledge of the requirements of human nutrition than perhaps any other series of investigations. This station and the Wisconsin station through similar protein investigations have had a large share in the development of the modern vitamin conception, essentially an outcome of protein studies. In the list of projects submitted by the Connecticut station under the heading of protein research and nutrition studies, three relate specifically to proteins. The first, on the proteins of green plants, is at present in the state in which it is difficult to trace any connection with human nutrition, but the progress of this investigation should be watched with interest. A continuation of the study of the part played by proteins, carbohydrates, and fats in nutrition has emphasized the fact that "so long as the 'law of minimum' is not violated, surprisingly large variations in the quantitative make-up of the diet may apparently be tolerated." As preliminary to a further study of the relation of the chemical structure of the proteins to their nutritive value, large quantities of pure amino acids have been prepared and are being used in feeding tests. Edestin has been shown to contain no oxyglutaminic acid, and, since edestin furnishes all the amino acids needed for growth, oxyglutaminic acid has thus been added to the list of nonessential amino acids.

Vitamins.—Vitamin studies are being conducted in at least 20 of the stations. Only the projects having a direct bearing upon human nutrition are listed in the above tabulation, but in addition to these there might be cited a long list of projects dealing with the vitamin requirements of chickens, cows, and pigs. The list of vitamin projects in poultry husbandry alone numbers 20. Although many of these have no bearing upon human nutrition, others are concerned with general principles applicable alike to animal and human nutrition.

The vitamin projects listed in this survey range from simple studies of their quantitative occurrence in various food products to fundamental research on their function in the animal body. One of the most important recent discoveries concerning vitamins came from the Wisconsin station in the work of Steenbock and his associates on the activation of food materials with respect to antirachitic properties through the action of ultraviolet light. Of direct application to human nutrition is the possibility of rendering palatable foods antirachitic for use in place of the dreaded cod liver oil. The value of sunlight in supplementing the antirachitic vitamin and promoting normal mineral metabolism is already being recognized in animal feeding and should be emphasized more strongly as an important factor in child nutrition.

Another phase of the vitamin work at the experiment stations which is of fundamental importance is the relation of vitamins to successful reproduction and lactation. This problem

is being approached at the Arkansas, Connecticut State, Minnesota, and Wisconsin stations. At the Arkansas station a study of the inadequacy of milk proteins for reproduction has led to the conclusion that the failure of milk is due not to lack of amino acids but of a substance of the nature of a vitamin. This is of interest in that the results obtained confirm in practically all respects those reported from the University of California by Evans and Bishop who were the first to announce the existence of a specific vitamin for reproduction. In his work at the Arkansas station, Sure considers that he has demonstrated also that the amount of vitamin B required for the normal function of the mammary gland is greater than that for growth, thus suggesting the need of supplying an additional amount of vitamin B during the lactation period.

At the Minnesota station a project entitled "Studies on the quantitative requirements of laboratory animals for vitamins" has developed along interesting lines, including the question of reproduction. Some evidence has been obtained in support of the theory of a specific vitamin for reproduction, the vitamin X of Evans and Bishop or E of Sure, but it is the opinion at the Minnesota station that both yeast and milk contain this vitamin. In addition evidence has been obtained pointing to the presence in cow's milk of another factor promoting lactation. This appears to be distinct from the other known vitamins. Evidence has also been obtained that still another factor is essential for normal physical well-being and possibly for growth. The lack of this factor in the diet of rats is followed by a peculiar greasy appearance of the fur. The condition may be cured or prevented by feeding small quantities of milk, protein-free milk, commercial lactose, and the like.

A practical vitamin project relating to milk is the study at the Nebraska station of the fat-soluble vitamin A content of the milk of different dairy breeds. One cubic centimeter daily of Jersey milk has proved sufficient to restore weight and health and check ophthalmia in rats on a ration deficient in vitamin A, but this quantity is not sufficient with Holstein milk.

These studies are cited not so much for the purpose of serving as a progress report on vitamin work at the stations as to illustrate the type of research which may be considered fundamental as compared with tests for vitamin occurrence (at least when not concerned with the discovery of principles governing such occurrence). Vitamin studies are still in their infancy and there are many problems which may very properly be investigated by home economics departments. One problem on which only a beginning has been made is the stability of the various vitamins during cooking and canning processes. One of the projects reported by the home economics department at the New York Cornell station, "An experimental study of the effect of various methods of canning carrots on their antiscorbutic properties," illustrates this type of vitamin research.

Mineral metabolism.—Closely bound up with studies dealing with the fat-soluble antirachitic vitamin are studies on mineral metabolism, particularly that of calcium and phosphorus. A review of the station work up to and including 1922 on fat-soluble vitamins, particularly in relation to mineral metabolism, was given in a previous report[5]. Many of the stations, including those of Iowa, Kansas, Michigan, Ohio, Oregon, and Wisconsin, are still engaged in such studies. As most of the projects at present listed in this connection deal with the nutrition of farm animals, they have not been included in the present survey, although undoubtedly of indirect application. In the same class might be considered studies at the Oregon and Washington stations on the significance of potassium and sodium in animal nutrition and at the Montana, North Dakota, and Wisconsin stations on the relation of iodine to animal nutrition. The study at the Kentucky station of the significance of manganese, copper, and zinc in reproduction and metabolism has been included in the present survey as possibly of more direct bearing upon human nutrition.

GENERAL OUTLOOK FOR HOME ECONOMICS RESEARCH AT THE EXPERIMENT STATIONS

Considering home economics research as an integral part of the work of the experiment stations, its present status, at least in the division of food and nutrition, is encouraging. Well-established lines of research in several departments are contributing funda-

[5] U. S. Dept. Agr., Off. Expt. Stas., Work and Expend. Agr. Expt. Stas., 1922, p. 79.

mental knowledge of application to human nutrition. With the development of research the home economics departments will be in position not only to carry on independent investigations but also to supplement materially the work of other departments by cooperative investigations along the lines indicated above, and others which will suggest themselves in connection with the individual problems confronting the various stations.

BREEDING WORK WITH FIELD CROPS AT THE EXPERIMENT STATIONS

By Henry M. Steece, *Specialist in Agronomy*

Breeding work with field crops at the State experiment stations has produced important practical results in crop improvement and has contributed much information of value concerning the principles of genetics and the refinement of technique. During the last 20 years, the application of Mendel's laws of heredity to crop plants and the use of improved methods of selection and pure line breeding have received much attention at the stations and have been very fruitful in results. This work supplements the highly valuable investigations of other American and foreign workers and of the United States Department of Agriculture. In the following pages attention is called to some of the inheritance studies carried on with the principal field crops, the relation of the mode of reproduction to crop breeding, and examples of the results of selection work and breeding for special adaptation.

INHERITANCE STUDIES WITH THE MAJOR FIELD CROPS

Corn.—Corn is the most important crop in the United States, and consequently the problems involved in its production and improvement have been investigated extensively at the experiment stations. The many efforts made to enhance yielding power and to produce uniform seed types have quite logically led to inquiry into the inheritance and interrelations of the factors concerned with yields and seed character. Inheritance of row character was evident at the New Jersey stations (145)[6] to the extent that the larger the number of rows in the parent ear the greater was the tendency to produce many-rowed and zigzag ears. The proportion of zigzag ears was greatest when taken from a zigzag parent ear. In studies made at the New York Cornell station (169) on the progenies of corn plants having wholly pistillate inflorescences, one a type called tassel seed and apparently entirely distinct from another type known as tassel ear, the two characters were shown to be linked and recessive.

Starchiness of kernel was found in studies at the Connecticut State station (23) and Bussey Institution to be a separate plant character independent of the physical form in which it exists. The characters giving the flint or dent appearance to corn seemed to be transmitted to the entire ear and not as endosperm characters to the individual seed. They showed segregation, and were held due to the action of more than one transmissible character. The podded character of pod corn was found to behave as a simple Mendelian dominant. A tendency for connate seed to be inherited was noted at the Virginia station (215). Continuously growing sporophytes observed in strains of corn at the Missouri station (127, 128) were due to two distinct factors inherited as simple recessives.

The inheritance of certain endosperm differences of various races of corn that have been made the basis of a division into the subspecies *Zea mays everta*, *indurata*, *indentata*, and *amylacea* and of the shape of seed characterizing the so-called rice pop corns was investigated at the Connecticut State station (25). Regardless of the variety used as the female parent, no immediate visible effect of the male parent appeared in the endosperm of crosses between flint and floury corn, and a cross between the floury and Leaming dent behaved similarly. In plants having fundamentally the same zygotic possibilities as regards the type of starch in the endosperm, the amount of soft starch actually developed is directly proportional to the size of seed. Pollen of White Rice pop corn apparently had no effect on the character of the endosperm of the floury type. The character for floury endosperm appeared to be recessive to that for flintiness at the New Jersey stations (146) and the form of flintiness classed as an ear or plant character was not read-

[6] Numbers in parentheses refer to references, p. 54.

ily transmitted through cross pollination to adjacent pure sweet grains (144). Linkage involving aleurone, endosperm, and chlorophyll factors has been investigated at the New York Cornell station (159, 162, 164, 166).

Defective seeds, heritable corn variations in which the endosperm is lacking or is incomplete or abnormal in its development, have appeared in all the so-called subspecies of corn with the possible exception of *Zea mays tunicata* and in more than 30 representative American varieties, as well as in several varieties from Spain and one from Peru. Genetic studies at the Connecticut State station (35) gave evidence that many different factors are involved which may cause defective seeds in corn. Scarred endosperm was shown at the Missouri station (126) to be inherited as a simple Mendelian recessive. Correlated with scarred endosperm was a difference in size of kernel apparently due to the same factor. An endosperm defect in sweet corn termed "sweet defective" (63) and another character known as miniature germ (64) were inherited as simple Mendelian recessives, at Iowa State college. The inheritance of a defective endosperm at the West Virginia station (228) seemed to be controlled by a single factor difference.

The inheritance of color in the different organs of the corn plant has been given considerable attention. An absolute, presumably genetic, correlation was apparent between color of cobs, pericarp, husks, silks, and anthers at the Nebraska station (136). A somatic variation concerned with the development of a dark red or brown pigment in the pericarp of the grains, often associated with an apparently similar pigment in the cob and husks, was shown (134) to be a simple Mendelian in inheritance. Purple aleurone color behaved as a normal Mendelian character at the Connecticut station (23). Studies involving the factors influencing the development of the various red sap colors appearing in the pericarp, the cob, the husks, the silks, the glumes, and the anthers showed that coupling sometimes occurred, but as a rule independent of the red in the other parts of the plant. A study made at the Connecticut and Minnesota stations (105) of the relation of various pericarp characters in crosses between the various homozygous types, suggested that certain combinations produce germinal instability, and led to conclusions that the factors for self-red, variegated, pattern, and colorless pericarp form a series of multiple allelomorphs.

From studies of the various categories at the Nebraska station (142) it appeared that in practically all cases the several types of albinism in corn leaves behave as simple Mendelian recessives. The inheritance of eight chlorophyll types was found to be strictly Mendelian and all were recessive to normal green at the New York Cornell station (154). Salmon and brown silks were shown at this station (157) to be recessive to green silks by a single factor pair. An exhaustive investigation at this station (156) dealt with the genetic and environmental relations of six major plant colors of corn—purple, sun-red, dilute purple, dilute sun-red, brown, and green (colorless), together with the subtypes—weak purple, weak sun-red, green-anthered purple, green-anthered sun-red, and five genotypes of green.

The relative size of plants was not transmitted to any degree at the Nebraska station (137) and variation in size of plant was considered due to some local cause rather than inherited. Further observations at that station (133) suggested that length of ear is directly correlated with height of plant and inversely correlated with number of rows per ear. Number of rows seems also to be related to the character of the endosperm. The interrelations of such characters as number of rows per ear, circumference of ear, and breadth of seeds are obvious. Absence of ligule and auricle seemed to be recessive at the Nebraska station (138) and independent of several common characters in corn in inheritance. A genetic analysis at the Missouri station (124) indicated that two factors were concerned in the inheritance of zigzag culms, such culms appearing only when both were recessive. Biometrical studies at the Virginia station (214) had to do with the ear and plant characters of corn, the inheritance of certain characters as influenced by hybridization, and inheritance of correlated characters.

Although numerous corn breeders and investigators have long sought for some character of the corn plant which could serve as an index to potential yields, correlation studies with corn failed to reveal plant or ear characters that were significantly related to yielding ability at the Nebraska (137), New York Cornell (149), Kansas (70, 72), Missouri (125), and Ohio (183) stations. The average circumference of the seed ear

was the only character showing any significant relation to yield at Cornell University (165). Continued selection at the Illinois station (52) apparently induced a certain correlation between the protein and oil content in corn and resulted in characteristic types of kernel and perceptible modifications in the type of ear. Selection for high protein was evidently accompanied by a reduction in yield. Height of ear and yield were to some extent positively correlated at the South Dakota station (202), the higher growing ears indicating heavier yielding strains of corn, however, later in maturing than the low-eared corn. It seemed at the Virginia station (216), that points emphasized in the corn score card may be of value in selecting high-yielding strains, and that high-yielding strains are high-scoring strains. According to other results at this station (218), ears which germinate early produce plants which ripen late, and the plants which tassel and silk early mature late and yield high.

Wheat.—The principal aim of wheat improvement is the production of high yielding varieties, but milling and baking quality and resistance to drought and disease are also important considerations. Through selection and hybridization, many of the experiment stations are engaged in breeding new varieties and improving existing types of wheat. Data accumulated during recent years on the inheritance of unit characters in wheat tend to show that the process of fixing new hybrids may be simplified, that the breeder may predict with a fair degree of assurance what combinations of unit characters may be associated and fixed in a new variety, and that new varieties having desired attributes and qualities may be bred with certainty.

From observations at the South Dakota station (201) the length of the central spike of wheat can not be considered as the indicator of the fitness of a given plant to serve as the mother of a line of progeny. Detailed study of the different modes of inheritance in crosses between *Triticum spelta* and *T. sativum* has been carried on at Cornell University (170) in cooperation with the United States Department of Agriculture. Squareheadedness, the result of a combination of growth characters, showed a complex mode of inheritance at the New York Cornell station (158) and was correlated to a certain extent with width of culms. Density was found dominant over laxness, and density and the shortening of the other length characters appeared to be the result of a single dwarfing factor. Further investigations (173) seemed to show that the spelt factor decidedly interferes with the full expression of the factors for density and those for squareheadedness. In studies of the inheritance of seed and spike characters in wheat crosses at the Minnesota station (99) indications were that length of seed is inherited similarly to other size characters; that the awn of wheat is apparently an important physiological organ; and that awned varieties may be expected to yield somewhat better than awnless wheat. A genetic linkage was apparent at the Arizona station (6) between one or more of the factors controlling the grain texture and head shape in the varieties of macaroni and bread wheat used as parents.

The genetic behavior of true softness in wheat may be explained by two independent factors which govern the relative proportion of gluten and starch, according to inheritance studies at the Arizona station (8). The genetic factors governing the appearance of yellow berry are evidently distinct from those producing true softness and are said to be very sensitive to environic influences. Genetic factors for sensitivity appeared to be inherited as definitely as are other factors governing quantitative characters. From the work at this station (7), the gradual softening of an impure race of wheat might be explained as climatic selection without the necessity of assuming any direct or accumulative influence of the climate upon the hereditary substance itself. Percentage of plumpness of seed was said to be an inherited character at the Minnesota station (116) and associated with high average yield per plant. Some strains produce a higher proportion of yellow-berry kernels than others, and in some cases this tendency is inherited.

Growth habit characters segregated in accordance with Mendelian laws in the progeny from Kanred×Marquis in Minnesota (119), the presence of multiple factors being indicated. In both direct and reciprocal crosses between true spring and true winter wheats at the New York Cornell station (172) the short vegetative period was dominant. Apparently a dominant factor for winter and an inhibitor against winter were involved. High tillering mother plants tended to produce a larger proportion of plants

with more tillers than the average at the Delaware station (36), but the inheritance of tillering as indicated by the performance of individual plants was not marked. When crossed with certain other normal varieties of wheat at the Washington station (223), Marquis, Baart, and Kubanka all produced a certain percentage of dwarf plants. Dwarfness seemed to be associated with late ripening and was possibly linked in some degree to winter habit. Dwarfness in wheat at the North Dakota station (181) was accompanied by unexpected ratios in segregation.

Correlation studies at the Delaware station (38) indicated that the number of sterile spikelets is likely to increase with the length of the wheat spike, whereas cytological studies at the Minnesota station (101) failed to show correlation between morphological and botanical head characters and sterility in wheat. The immediate progeny of Marquis wheat appeared to make higher yields from long spikes than from relatively short spikes at the South Dakota station (203), but this correlation did not seem to persist.

The relationships existing between crude protein, dry gluten, gliadin, water absorption, flour yield, and loaf volume for the wheats found in different parts of the country have been compared at the Maine station (84). Correlations between protein content and crushing or breaking point of the kernel, specific gravity, and volume of the grain were either very slight or nil in studies at the Kansas station (73). Wheat kernel plumpness was not found to be correlated significantly with crude protein (or crude gluten) content at the Minnesota station (117).

Oats.—The possibilities of improving the oats crop by the selection of good plants from a variety or by combining through hybridization the desirable qualities of different varieties have been shown at Cornell University (163). The inheritance of certain glume characters in the cross *Avena fatua*×*A. sativa* have been reported in detail from the Maine station (87). Crosses between hulled and naked types of oats at Cornell University (167) and at the Maine station (88) segregated in a ratio of 1 hulled, 2 intermediate, 1 naked. A nearly complete dominance of the awnless condition was observed in a cross between the fully awned Burt and the awnless Sixty Day types at the New York Cornell station (155). Both parents seemed to contain the factor for awning, but this was prevented from operating in Sixty Day oats by an inhibitor closely linked with the factor for yellow color in that variety. Strong linkage was noted between the fully awned condition and the medium long hairs at the base of the grain and the Burt type of basal articulation. Extensive investigations at this station (151, 152, 153) in cooperation with the United States Department of Agriculture were made to determine characters in the oats plant which could be used as bases for selection and to determine the status of correlation of characters in oats.

A study of *Avena sterilis* × *A. orientalis* at the Washington station (226) showed that resistance to smut was completely dominant and apparently caused by multiple factors. The black color of the floral glume of *A. orientalis* behaved as a simple dominant, while the shape of the panicle was probably determined by multiple factors. When crossed with white hulled varieties at this station (221), one variety of white hull-less oats produced black oats. Hull-lessness prevented the development of glume color in the parent and hybrids of all the crosses tested. The behavior of oats hybrids at the Minnesota station (97) showed that rust resistance is inherited as a dominant character depending on a single factor difference for its expression, and panicle type apparently depends on a single main factor for expression. Neither character seemed to be closely linked in inheritance.

Barley.—That crossing, even though taking longer, will prove better than selection for the ultimate improvement of barley was indicated by nursery results at the Minnesota station (95). However, the value of the pure-line method of breeding was not disputed. Hooded barley was dominant over bearded, covered over bald, and 2-row over 6-row at the Washington station (221). The characters were produced by multiple factors or were irregular in inheritance. The Minnesota station concluded from investigations made in cooperation with the United States Department of Agriculture (104) that internode length in the barley rachis is a very stable character, much less affected by environmental conditions than many size characters. The occurrence of *Hordeum intermedium* and other segregates in the progeny of a cross of

Manchuria and Svanhals barleys has been described from results obtained in similar cooperation (111). The linkage or independent assortment of a number of genetic factors in barley has been studied at the University of California (19).

Cotton.—Improvement of cereals has been an outstanding phase of plant breeding work in this country, but the other field crops have by no means been neglected. The southern stations, notably Arkansas, Alabama, Mississippi, North Carolina, Oklahoma, South Carolina, and Texas, have worked with new or improved strains of cotton which promise better yields and quality of lint, and genetic studies with this crop are beginning to show results. The heritable characters in cotton crosses observed at the Georgia station (46) seemed to obey Mendel's law of dominance, segregation, and recombination. Observations on different varieties of cotton at Georgia State College (47) indicated that the marked differences which exist between varieties in the oil content of the seed remain fairly constant, and are transmitted from generation to generation. High and low oil contents in cottonseed were maintained during several generations at the Texas station (206). Other aspects of breeding work with cotton are discussed under succeeding topics.

Potatoes.—Expansion of the potato industry in the United States has created demands on the plant breeder for varieties adapted to certain regions or environmental conditions, possessing specific qualities, and resisting diseases. A few of the results of genetic and correlation studies made in response to these demands will be described briefly here, and selection work with potatoes will be discussed later.

By stimulating seed production through prevention of tuber formation by removing the earth from around the stolon, in experiments at the Connecticut State station (28), characteristic differences in seeding power were found which are inherited by different varieties. Although the large variations in these characters could be increased artificially by changing environmental conditions, no ordinary treatment would force a variety across its critical point into another biotype. According to results at the Minnesota station (115), tuber shape depends essentially on the presence or absence of a single factor for length. Both early and late-maturing seedlings were obtained in F_2. Although the heterozygous condition of the parent varieties complicates matters, it does not appear to prevent the combining of the desirable characters of the parent varieties into a commercial variety, if large enough populations can be grown.

Only those correlations where color was manifested in different parts of the plant exceeded the probable error in a study of correlations between potato characters at the Connecticut State station (28). In the fall crop of Lookout Mountain potatoes at the South Carolina station (198), vegetative growth was highly correlated with seed production and with yield of tubers, while a lesser degree of correlation was found between seed production and tuber yield, apparently indicating that conditions favoring one character also favor the others and that no mutual antagonism exists between the several characters rather than an inherent connection between the characters. No relation seemed to exist between the yield of marketable tubers and the tuber characters of Green Mountain potatoes at the Virginia station (217). However, the yield of marketable tubers had a high positive correlation with the number of tubers produced and a significant negative correlation with the yield of nonmarketable tubers. Other correlations were recorded between tuber characters at this station and at the Minnesota station (118). Shallowness of eye was found by the Montana station (131) to be correlated with degeneracy.

Sorghum and sugar cane.—Although the improvement of the sorghums has been largely achieved by selection, several characters have been subjected to genetic analysis. In crosses between dwarf milo and feterita studied by the United States Department of Agriculture partly in cooperation with the Texas station (209), the awn was found to be recessive, and the broad truncated shape of the awned milo glumes were dominant over the narrower ovate shape of the awnless feterita glumes. When Red Amber sorgo was used as the pistillate parent in several crosses, the red in its glumes was found dominant over the black in glumes of feterita, with only a single factor difference between red and black glumes. The uniformly red-brown seed color of Red Amber sorgo was dominant over the bluish-white seed color of feterita,

with two independent unit factors apparently involved in the determination of seed color.

No evidence of the transmission of an abnormal spur at the base of the kafir head to the progeny was obtained at the Lubbock, Tex., substation (207). In hybrids between Blackhull kafir and Red kafir, the Red kafir type and shape of head was dominant, while the seed color was intermediate. According to other studies at this substation (210) the so-called varieties of milo and of kafir seem to differ from one another in seed coat color by a single factor, whereas different classes or groups of sorghum, such as feterita and kafir or feterita and Red Amber, differ by two or more factors affecting seed coat color. The lack of hybrid vigor in any of the crosses of milo on milo or kafir on kafir and the extraordinary heterosis shown in the F_1 generation of crosses between classes or groups of sorghum further indicates more genetic differences between classes or groups than exist between the different forms of milo or kafir.

Seedling sugar canes in the F_1 generation in Porto Rico (196) somewhat resembled the parent varieties of sugar cane, particularly as to color. Seedlings showed wider variations than canes produced from cuttings of the same variety. New types of cane were obtained by crossing different varieties, variation appearing to be increased by such combination.

Soy beans and velvet beans.—The inheritance of characters in soy beans has been studied to a rather limited extent. Dark colored and light colored pods in soy beans studied at Wisconsin station (238) constituted an allelomorphic pair of characters, dark being dominant to light and differing from it by a single factor pair. Purple (colored) and white flower color (recessive) constitute a simple Mendelian pair of characters. Perfect correlation apparently exists between flower color and stem color, such that purple flowers always accompany purple stems, and white flowers, green stems. In the progeny of a cross with black Venezuelan beans at the Porto Rico station (193), blackness of the seed coat was found to be dominant over whiteness and glossiness over dullness. The genetic relations of some of the characters of the velvet bean have been investigated at the Florida station (39, 40, 41, 42, 43, 44). In this work the Florida velvet bean (*Stizolobium deeringianum*) was crossed extensively with the Lyon bean (*S. niveum*) and also with the Yokohama and China velvet beans.

Tobacco.—Breeding work with the tobacco plant not only has its economic aspects, but the tobacco genus Nicotiana is considered especially favorable material in the study of plant genetics. Extensive experiments with tobacco at the Connecticut State station (24) produced results in accord with the hypothesis that the inheritance of quantitative characters, such as size, shape, and number of various plant organs, may be due to the interaction of a multiplicity of factors, each inherited separately and capable of adding to the character. From the plant breeding standpoint there seemed good reason for believing that quantitative characters are inherited in the same manner as qualitative characters. The branching or suckering habit of tobacco appeared to be a distinct characteristic and to behave as other inherited characters at the Wisconsin station (235), although subject to considerable variation, because of environmental and physiological factors. The inheritance of this habit is regarded as purely quantitative and not separable into satisfactory classes or ratios.

Crossing certain varieties of *Nicotiana tabacum* at the California station (13) demonstrated the complexity of difference from a genetic standpoint between any two of the so-called fundamental varieties of *N. tabacum*, and showed the futility of seeking to determine affinities on the basis of morphological studies unaccompanied by experimental investigations. The genetic studies led to the conclusion that all *N. tabacum* varieties must be regarded as fundamentally equivalent from a genetic standpoint. In addition to these crosses (14), a series of papers on inheritance in *N. tabacum*, reporting investigations at the California station, were also concerned with the existence of genetically distinct red-flowering varieties (15), the occurrence of two natural periclinal chimeras (16), the trisomic character "enlarged" (17), and the occurrence of haploid plants in interspecific progenies (18).

RELATION OF THE MODE OF REPRODUCTION TO CROP BREEDING

The breeding work and genetic studies at the stations have produced much information in regard to the effects of inbreeding, hybridization, natural cross pollination, the causes of hybrid vigor and sterility, and the behavior of mutations.

Pollination.—Pollination studies have shown differences in seed production and the existence of self-fertile lines in red clover in Kentucky (74), self-fertility in vetch in Oregon (185), the deleterious effects of selfing corn in Nebraska (140) and in Minnesota (106), and self-sterility in sunflowers in Montana (129). Failure to get potato seed may be due to hereditary sterility of the pollen, unfavorable environmental conditions, and the shedding of the blossoms, which is probably the manifestation of the first two causes, according to studies at the South Carolina station (198). Self-fertilized clonal lines of timothy studied at the Minnesota station (114) varied widely in the quantity of seed set, probably due to genetic causes.

Inbreeding.—The effects of inbreeding of normally crossed fertilized crops have been studied most extensively in corn. Adverse results followed inbreeding of corn at the Nebraska (139), Mississippi (122), Pennsylvania (186), and Wisconsin (234) stations in contrast to the favorable showing made under open pollination or by hybridization. By the use of indices related to enzymatic activity, highly inbred corn that in some cases equaled crossbred corn in vigor, was obtained at the Delaware station (37). The varieties sustaining inbreeding best at the Mississippi station were usually those yielding well in other tests. Inbreeding kafir at the Texas station (211) did not cause a reduction or increase in the size of the head or in productivity, except in so far as it has isolated subvarieties differing from the parent family.

Hybrid vigor, as exhibited in crosses between varieties of corn, has been considered responsible for increased yields or resistance to adverse environmental conditions at the New Jersey (143), Connecticut (27, 30), North Dakota (180), Kansas (69), Nebraska (139), and Virginia (213) stations. On the other hand only slight or unprofitable increases were obtained at the Mississippi (122), Pennsylvania (186), and Minnesota (96a) stations. The only type of F_1 varietal cross proving of much value in Minnesota was the hybrid between an early flint and a later dent which appeared of promise for northern Minnesota. If selection to ear type is not closely followed, it is concluded that the use of F_1 crosses between standard varieties will not lead to a material increase in yield. Results at the Connecticut stations (31) and elsewhere supported the assumption that hybrid vigor results from assembling the greatest number of favorable growth factors and not from an indefinite physiological stimulation. Crosses between varieties of diverse type therefore possess more favorable growth factors than crosses between similar varieties, and hence give larger increases when crossed. Hybrids between selected self-fertilized lines of corn have outyielded the highest producing varieties grown at the Connecticut State station (27). Likewise at the Nebraska station (141) hybridization of self-fertilized lines seemed to be the most promising method of corn improvement.

Crossing normally self-fertilized crops.—Natural hybridization or vicinism is of the greatest interest from the viewpoint of normally self-fertilized crops. Limited experiments at the Georgia station showed that natural crossing occurs in cotton (46). While rather low percentages of natural hybrids in cotton resulted at the Mississippi station (121), varietal differences were apparent. Only a few of the ovules seem to be affected in the natural crossing of a flower. Preliminary observations at the Texas station indicated that an average of 6 per cent of natural cross-fertilization occurred in white milo plants mechanically introduced into a plat of yellow milo (208). Natural cross-pollination in grain sorghums averaging 1.67 per cent was also noted at Lubbock, Tex. (207). Natural hybrids were so numerous in soy bean varietal plats at the Indiana station that artificial hybridization was not thought necessary to produce new sorts (60). According to observations at the Wisconsin station (237), if all ways in which crossing may occur in soy beans are considered the proportion would be 1 hybrid pod in 625, or 0.16 per cent. The percentage may presumably differ with the variety, the locality, and the season.

The observed crossing in lines of *Triticum vulgare* amounted to 1.3 per cent at the Minnesota station (107), and assuming that it occurred as often within the variety as between different sorts natural crossing in 1917 probably ranged from 2 to 3 per cent. The appearance of F_1 plants in supposedly pure lines of wheat is thought to have led to the belief that hybrids frequently revert to type. The results obtained in experiments at this station and at Arlington, Va. (109), showed the necessity of protecting

emasculated flowers from undesired pollination in studies of inheritance in wheat hybrids and in breeding operations where hybrids of known parentage are desired. Natural crossing in wheat has also been reported on from the West Virginia station (227).

Examples of hybrid vigor observed in normally self-fertilized species may be cited. F_1 hybrids of certain pure lines of cotton proved earlier, more vigorous, and more productive than either parent at the North Carolina station (176). Seedlings from hybrid sugar cane seed appeared to grow stronger and with greater vigor at the Porto Rico insular station (195) than those from uncrossed seeds. The lack of hybrid vigor in any of the crosses of milo on milo or kafir on kafir employed in studies at the Texas station (210) would indicate a close relationship between the milos and between the kafirs, especially in growth factors. Where the phenomenon was distinct at Iowa State College (65) practically all the indications of heterosis in F_1 hybrids between soy bean varieties were made within the three weeks prior to cessation of growth. In yields per plant, the percentage increases of the hybrids over the parents ranged from 59.6 to 394.4. One of the immediate effects of cross-pollination, noted in studies at the Minnesota station (113) of the increased vigor of F_1 crosses between species and varieties of Triticum, was an increase in seed weight in all varietal crosses. In all varietal crosses the F_1 hybrid surpassed the parental average in yield of grain per plant.

Sterility.—Evidence of the inheritance of sterility in corn was obtained at the New Jersey stations (147) and the South Carolina station (199). At the latter station barrenness was apparently correlated with such characters as color, size, and shape of plant, and length of life.

Varieties of wheat grown under field conditions at the Delaware station (38) exhibited a higher percentage of sterile spikelets than where the plants were spaced 6 inches apart, as in the centgener method. Sterile spikelets were more profuse in the awned varieties than in the awnless and in the earlier plantings as compared with later seedings. The number of sterile spikelets appeared likely to increase with the length of the spike. The F_1 generation of crosses of emmer or Mindum with varieties of *Triticum vulgare* or with Little Club showed a high degree of sterility at the Minnesota station (113). The Maine station reports (83) that the wheat varieties in the einkorn group are interfertile but are sterile or only slightly fertile with the emmer and vulgare groups. The species and varieties of the emmer group are interfertile but are partially sterile with the vulgare group which are also interfertile. The size of the pollen grains appears to vary in different species of Triticum, and seems to be closely correlated with the sterility relationships of the three groups mentioned above, although it is said to have little or no effect on the percentage of grain set in crossings. A high proportion (85) of abnormal pollen grains was noted in the F_1 of crosses between the groups bearing 7 and 14, and 14 and 21 genetic chromosomes. Although crosses between wheats differing in chromosome number may result in small, wrinkled grain and more or less sterility in the F_1 generation, little or no correlation was found by the Maine station (86) between F_2 endosperm development and F_2 sterility or vegetative development.

A study of hybrids of several species of Stizolobium at the Florida station (45) suggested that the degree of sterility of some hybrid plants may be determined accurately by microscopic examination of the pollen of healthy flowers and sections of the ovules. The random abortion of half the pollen grains and half the embryo sacs is apparently due to the segregation of Mendelian factors and not to the action of these factors on the zygotes. Timothy was found to be highly self-sterile under conditions at the Minnesota station (99).

Bud variations and mutations.—Apparent mutations have been found in the course of breeding work at several stations and their characteristics have been studied. The behavior of variations in the potato reproduced by budding at the Connecticut State station (29) appeared to be in many ways essentially like that of variations coming from seed. Practically all of the variations found concerned characters that Mendelize in sexual reproduction. Since no changes of commercial value have been found, asexual selection could hardly be recommended as a commercial means of actual improvement. An eversporting type of buckwheat was studied at the Maine station (81). Blotch leaf of corn, inherited as a recessive, or nearly recessive, character is believed at the

New York Cornell station (161) to have originated as a somatic mutation in a single plant. The development of two flowers in the corn spikelet is considered by this station (160) to be a reversion toward a more primitive many-flowered condition. Bud variations in tobacco have been observed at the California station (10) and Connecticut State station (33). Bud selection experiments with sugar cane at the Porto Rico station (194) gave negative results.

CYTOLOGY

The cytological work that has been reported for the more common crop plants has been described as limited and fragmentary. In an effort to meet the need of students and practical plant breeders for such information, a cytological study of the pistillate spikelet and flower of the corn plant was made at the Kansas station (70a). The chlorophyll types of corn were studied at Cornell University (171) to determine if any visible structural differences in the cells could be responsible for or correlated with the known genetic behavior of these plants.

That einkorn possesses 7 haploid chromosomes; the emmer group, consisting of *Triticum dicoccum*, *T. durum*, *T. turgidum*, and *T. polonicum*, has 14 haploid chromosomes; and the vulgare group, consisting of *T. vulgare* and *T. compactum*, has 21 haploid chromosomes, was shown in cytological investigations at the Maine station (89). The chromosome behavior in partially sterile hybrids between different species of the foregoing groups has also been the subject of extensive study (85). The sterility, genetics, and cytology of a number of wheat species crosses were studied cooperatively by the Maine and Washington stations (90). Cytological studies in wheat at the Minnesota station (101) failed to show a correlation between morphological and botanical head characters and sterility. The development of the microspore and male gametophyte and of the megaspore and female gametophyte of wheat, fertilization and early embryonic development, and endosperm development have been given attention at the Washington station (222).

SELECTION

The aim of selection is to isolate the types of plant which most closely approach the ideal and to choose systematically from the produce of these types the variations most likely to be of economic value. The extent and characteristics of numerous variations of more or less significance in improvement work have been studied in brome grass at the Colorado (20) and North Dakota (178) stations, buckwheat in Maine (81), corn in Illinois (51) and Maine (78), kafir in Texas (205), peas in Massachusetts (92), oats in Maine (77), sunflowers in California (12), timothy in New York (148, 150), tobacco in Connecticut and Massachusetts (32), and in California (11), and wheat in Ohio (184).

Selection has improved the ability of alfalfa to produce seed at the Colorado station (21), altered plant characters in corn in Guam (48), and raised and lowered the oil and protein contents, position of the ear, and yields of corn at the Illinois station (52, 53, 55). Score card selection of corn seemed without practical value at the Minnesota station (96) and apparently would reduce yields if continued long without introduction of new blood. Ear type selections with corn appeared at the Nebraska station (135) to indirectly result in a selection of the correlated plant characteristics, which differ in their adaptation to various environmental conditions. Type of cotton plant could not be considered as an index to the potential productivity at the Arkansas station (9).

Selection within pure lines of oats was without effect at the Michigan (94) and Maine (79) stations. In all cases at the latter station (80) the average yield of the pure lines selected from a given variety of oats exceeded the yield of the parent variety. Among oats selections which have proved their practical value may be mentioned Iowa 103, Iowa 105, and Iowar, all of which are pure-line selections from Kherson, made at the Iowa station (62).

In the case of the potato, according to Stuart (239), selection implies the isolation and asexual propagation of desirable strains or types. The limitations of selection are those found within the varieties themselves. In line selection work with potatoes at the Montana station (132), selection based on vine development alone promised to be more reliable and practical than selection based on tuber production either by weight or number. Since a close correlation is indicated between top characters and productivity, selection based on top char-

acters is deemed not only safer but easier than bin selection (130).

Efforts made at the Minnesota station (110) to select strains resistant to degeneration ended in failure. High and low-yielding hills and tubers possessing so-called desirable and undesirable characters followed the same course, low-yielding hills often giving the better results. No difference was found in Minnesota (100) in the yield or form of tubers between lots of Early Ohio potatoes obtained from growers who had practiced continuous selection in the same seed stock for 20 years or more and those from growers practicing little or no selection. Potato varieties apparently do not run into definite strains and are relatively stable under vegetative propagation, according to results at the Minnesota station (118). The method of asexual selection did not seem to offer reasonable hope for their further improvement. Selecting eight different types of White McCormick for three years at the Maryland station (91) failed to give an increase of the desired types. In tests at the Utah station (212) concerning the power of a strain of potatoes to transmit its desirable qualities to succeeding generations, selected strains were superior in growth and yield factors to unselected potatoes of the same variety.

High-line and low-line strains in soy beans have been isolated at the Wisconsin station (233) in selecting for increased oil content, but the quality of oil was not changed. A definite relation was noted between plant height and quality of oil. Both high and low producing strains were isolated (232). Strains of soy beans producing higher percentages of oil were obtained at the North Carolina station (175), but they were the poorest yielders, and the largest quantity of oil per acre came from those strains yielding the most seed. Selection has also produced sugar canes with high sugar contents at the Louisiana (75) and Virgin Islands (219) stations, richer sugar beets in South Dakota (200), and improved varieties of timothy in New York (150), Pennsylvania (188), and Minnesota (99). Improved types of tobacco also were obtained in Wisconsin (229), Pennsylvania (187), and Connecticut (26).

Under the same environmental conditions in Maine (82), pure lines of wheat showed distinct differences in physical and chemical characteristics and in the bread value of their grain. In experiments at the Washington station (220), high or low nitrogen content did not seem to be a property of wheat which can be fixed by line selection.

BREEDING FOR SPECIAL ADAPTATIONS

Droughts, unfavorable environment, insects, and diseases have always hindered crop production and constantly serve to stimulate the efforts of plant breeders. Some degree of success has been attained by the introduction or breeding of strains resistant to one or more of these factors, and investigations in progress are very promising.

Drought resistance.—Differences in the relative drought resistance of pure races of alfalfa were seen at the Kansas station (66) and several hybrid strains of corn showed superior drought resistance (67). That varieties of alfalfa differ markedly in their ability to become more or less dormant during seasons of extreme heat or water famine was observed at the Arizona station (3). Breeding experiments at this station (4) have produced a hardy and drought and heat resistant variety of sweet corn from a few grains originally found among the native corn grown by the Papago Indians. Certain strains of Turkey wheat, all of which were hard when grown in the Central Plains States, immediately became soft when grown in Arizona (5) under irrigation, whereas other strains from the same sources have remained hard and retained their ability to produce high yields. Some tobacco hybrids produced in Ohio (182) exhibited great drought resistance and others showed exceptional ability to use profitably the less available or more slowly available forms of plant food.

Cold resistance.—Breeding work for cold-resistance in corn at the Wisconsin station (231) developed a strain of Golden Glow corn said to germinate when planted about 10 days earlier than usual. This strain was also characterized by early maturity.

Resistance to lodging.—None of the morphological characters in the cereals studied at the Minnesota station (108), except thickness of cell wall appeared to be closely related to lodging. In general, lodging in cereals may be said to depend upon so many factors of unequal value in the different sorts that no single factor seems to be closely enough correlated with it to be of much value as a selection index in cereal improvement.

Insect resistance.—Field observations in the presence of from moderate to severe chinch bug (second brood) infestation in southern Illinois, suggested that the greater yield of certain corn varieties is due to plant vigor as manifested by such varietal characteristics as large and sturdy stalks, well-developed root systems, and large leaf surfaces (54). The higher yield in White Democrat corn and several other corn varieties of Illinois seemed to be entirely due to their power to resist chinch bug attack (58). While both the roots and foliage of corn plants were heavily infested with aphids, none was discovered upon either the teosinte or teosinte×corn hybrids near by (56). Hybrid corns whose parent stocks came from Guam and Cuba appeared to resist the injury of the leafhopper more than imported corn belt varieties at the College of Hawaii (49) and were reasonably sure croppers, particularly in the lowlands.

In a comparison at the Kansas station (68) of 87 varieties of small grain, mostly wheat, the Hessian fly seldom laid eggs on oats, barley, einkorn, spring emmer, or durum wheat, and less abundantly on soft winter wheats than on hard winter wheats. Very few "flaxseeds" developed on certain varieties, notably Illini Chief, Dawson Golden Chaff, Beechwood Hybrid, and Currell Selection, although eggs were laid on the plants in abundance.

Observations at the Mississippi station (123) on the relative resistance and susceptibility of the bolls of different cotton varieties to boll-weevil attack seemed to indicate that varieties with the shorter boll periods, usually small bolled sorts, got beyond damage earlier than varieties requiring a longer period for development, which were generally large bolled.

Disease resistance.—Genetic studies made in conjunction with pathological investigations have produced results not only of scientific interest but possessing economic importance. Barren cornstalks and stalks bearing only nubbins appeared to be correlated with certain pathological conditions in the plants in cooperative studies by the Illinois station (57) and the United States Department of Agriculture. The genetic factors responsible for the reduced root systems in the strains of corn susceptible to root rot and leaf firing, respectively, appear to be recessive (59). Evidence at the Connecticut State station (34) from inbred strains of corn and their F_1 and F_2 hybrids suggested that susceptibility to smut (*Ustilago zeæ*) and a leaf-blight fungus is governed by factors capable of being segregated into some lines and not into others, the modification of the expression of parasitism by the vigor of the plants being a minor consideration.

Experiments by the United States Department of Agriculture conducted at Cornell University (168) yielded evidence that susceptibility to crown rust in Burt×Sixty-Day oats is partially dominant, while resistance is recessive, apparently due to definite genetic factors, although probably affected by nonhereditary factors. Rust resistance and susceptibility could hardly be considered as simple characters or determined by a single factor difference. At the Minnesota station (97) stem rust resistance in oats seemed to be inherited as a dominant character, depending on a single factor difference for expression. Rust reaction and panicle type did not appear closely linked in inheritance.

Resistance to smut in oats was completely dominant and apparently caused by multiple factors at the Washington station (226). Markton, a variety of common oats, was found to be immune from covered smut at this station (224). That some varieties of oats contain one factor pair for resistance to loose smut, whereas in other varieties two or three factor pairs may be concerned, is indicated by data obtained at Cornell University (174). The possibility of obtaining desirable types of smut resistant oats from crosses between resistant and susceptible varieties was indicated by the results.

Observations at the Kansas station (71) indicated three hard winter wheats that are resistant under Kansas conditions to a number of plant diseases, particularly stem rust and leaf rust. A selection of Fulcaster at the Pennsylvania station (190) seemed much more resistant to rust than most of the soft winter sorts, though less resistant than Crimean wheats, such as Turkey and Kanred. From studies at the Washington station (225), resistance of wheat to bunt, if Mendelian, is composed of multiple factors. Different wheat varieties possess different kinds of resistance, and linkage between resistance and morphological characteristics is not deemed sufficient to prevent the selection of a resistant strain of any morphological type desired.

Studies of a family derived from a durum-common wheat cross at the

North Dakota station (177) suggested that more than one factor is responsible for resistance to stem rust. Linkage was found to occur between the characters defining durum wheat and resistance to stem rust. Numerous distinct biologic forms of black stem rust (*Puccinia graminis*) have been isolated at the Minnesota station (112, 119, 120) from varieties of wheat. With the wheats used, it was found possible to combine in a single variety, resistance to two biologic forms of stem rust of wheat, when crosses were made between two varieties which reacted reciprocally to these rust forms. In work on the genetics of rust resistance at this station (102), immunity was found dominant, and a single factor was believed to determine the reaction to several forms of the rust.

Selections of varieties of cotton and of hybrids have been compared for wilt resistance at the Alabama (1) and Mississippi (121) stations and at the Georgia College of Agriculture (47). Potato hybrids showed varying degrees of susceptibility to wart disease at the Pennsylvania station (191) in work in cooperation with the United States Department of Agriculture. A hybrid potato blight-resistant in Hawaii (50) did not seem to retain this character on the island of Oahu. Strains of tobacco resistant to *Thielavia basicola* produced yields double those of infected strains at the Pennsylvania station (189). Susceptibility to this organism is considered recessive from studies at the Wisconsin station (236).

Baltic alfalfa showed resistance to a bacterial disease at the Colorado station (22), barley crosses to *Helminthosporium sativum* at the Minnesota station (98), flax selections to wilt at the North Dakota station (179), red clover selections to anthracnose at the Tennessee station (204), L–511 sugar cane to mosaic in Louisiana (76), seedlings of D. 109 and Java 36 sugar cane to mottling disease at the Porto Rico station (192), Yellow Caledonia sugar cane to gumming disease at the Porto Rico insular station (197), and a South American variety of sunflowers to rust at the Michigan station (93).

After three years' growth by the Minnesota station (103) of resistant flax varieties on clean soil the resistant qualities apparently were not lost in the absence of the wilt organism. According to preliminary indications, subsequent selection does not increase resistance to flax wilt with individual plant selections. Resistance to this disease appeared to be a dominant character at the Wisconsin station (230). High resistance to or even practically complete immunity from the leaf rust of rye (*Puccinia dispersa*) was shown by some sorts of rye at the Indiana station (61) in cooperative studies with the United States Department of Agriculture. Although resistance was probably dominant, complicating factors were suggested.

CONCLUSIONS

The scope and trend of breeding work with field crops in progress at the experiment stations during the last 20 years have been outlined in the foregoing review. The accomplishments are notable for their economic and scientific value, yet many problems remain to be solved. Among the promising lines for further research are investigations of the inheritance of earliness in certain cereals and cotton, studies of the characters concerned with yield, and genetic analyses of the factors involved in resistance to drought, diseases, insects, and to lodging and unfavorable soil conditions. Legumes, grasses, and the sorghums will undoubtedly receive more attention in the future. Additional cytological studies with important crops would supply much information essential to rapid progress in plant breeding investigations.

REFERENCES

(1) Wilt-resistant varieties of cotton. E. F. Cauthen. Ala. Sta. Bul. 189. 1916.
(2) Ala. Sta. Circ. 44, pp. 16, 17. 1921.
(3) Ariz. Sta. Rpt. 1913, pp. 257–261.
(4) Ariz. Sta. Rpt. 1914, pp. 345, 346.
(5) Ariz. Sta. Rpt. 1915, p. 538.
(6) Linked quantitative characters in wheat crosses. G. F. Freeman. Amer. Nat., 51 (1917), No. 611, pp. 683–689.
(7) A mechanical explanation of progressive changes in the proportions of hard and soft kernels in wheat. G. F. Freeman. Jour. Amer. Soc. Agron., 10 (1918), No. 1, pp. 23–28.
(8) Producing bread-making wheats for warm climates. G. F. Freeman. Jour. Heredity, 9 (1918), No. 5, pp. 211–226.
(9) Results of seven years' pedigree selection in Trice cotton. E. A. Hodson. Ark. Sta. Bul 171. 1920.
(10) Calif. Sta. Rpt. 1921, p. 93.
(11) Variation of flower size in Nicotiana. T. H. Goodspeed and R. E. Clausen. Natl. Acad. Sci. Proc., 1 (1915), No. 6, pp. 333–338.
(12) Growth and variability in Helianthus. H. S. Reed. Amer. Jour. Bot., 6 (1919), No. 6, pp. 252–271.

(13) A preliminary note on the results of crossing certain varieties of *Nicotiana tabacum.* W. A. Setchell, T. H. Goodspeed, and R. E. Clausen. Natl. Acad. Sci. Proc., 7 (1921), No. 2, pp. 50–56.
(14) Inheritance in *Nicotiana tabacum.*—I. A report on the results of crossing certain varieties. W. A. Setchell, T. H. Goodspeed, and R. E. Clausen. Calif. Univ. Pubs., Bot., 5 (1922), No. 17, pp. 457–582.
(15) Inheritance in *Nicotiana tabacum.*—II. On the existence of genetically distinct red-flowering varieties. R. E. Clausen and T. H. Goodspeed. Amer. Nat., 55 (1921), No. 639, pp. 328–334.
(16) Inheritance in *Nicotiana tabacum.*—III. The occurrence of two natural periclinal chimeras. R. E. Clausen and T. H. Goodspeed. Genetics, 8 (1923), No. 2, pp. 97–105.
(17) Inheritance in *Nicotiana tabacum.*—IV, The trisomic character, "enlarged." R. E. Clausen and T. H. Goodspeed. Genetics, 9 (1924), No. 2, pp. 181–197.
(18) Inheritance in *Nicotiana tabacum.*—V, The occurrence of haploid plants in interspecific progenies. R. E. Clausen and M. C. Mann. Natl. Acad. Sci. Proc., 10 (1924), No. 4, pp. 121–124.
(19) Interrelations of genetic factors in barley. K. S. Hor. Genetics, 9 (1924), No. 2, pp. 151–180.
(20) Variation studies in brome grass. A. Keyser. Colo. Sta. Bul. 190. 1913.
(21) Factors that affect alfalfa seed yields. P. K. Blinn. Colo. Sta. Bul. 257. 1920.
(22) Colo. Sta. Rpt. 1910, pp. 76–78.
(23) Inheritance in maize. E. M. East and H. K. Hayes. Conn. State Sta. Bul. 167. 1911.
(24) Tobacco breeding in Connecticut. H. K. Hayes, E. M. East, and E. G. Beinhart. Conn. State Sta. Bul. 176. 1913.
(25) Further experiments on inheritance in maize. H. K. Hayes and E. M. East. Conn. State Sta. Bul. 188. 1915.
(26) Connecticut Round Tip tobacco: A new type of wrapper leaf. D. F. Jones. Conn. State Sta. Bul. 228. 1921.
(27) Conn. State Sta. Bul. 254 (Rpt. 1923), pp. 154–156. 1924.
(28) Conn. State Sta. Rpt. 1907–8, pt. 7, pp. 429–447.
(29) Conn. State Sta. Rpt. 1909–10, pp. 119–160.
(30) Conn. State Sta. Rpt. 1913, pt. 6, pp. 353–384.
(31) Conn. State Sta. Rpt. 1916, pt. 5, pp. 323–347.
(32) Variation in tobacco. H. K. Hayes. Jour. Heredity, 5 (1914), No. 1, pp. 40–46.
(33) Mutation in tobacco. H. K. Hayes and E. G. Beinhart. Science, n. ser., 39 (1914), No. 992, pp. 34, 35.
(34) Segregation of susceptibility to parasitism in maize. D. F. Jones. Amer. Jour. Bot., 5 (1918), No. 6, pp. 295–300.
(35) The inheritance of defective seeds in maize. P. C. Mangelsdorf. Jour. Heredity, 14 (1923), No. 3, pp. 119–125.
(36) The tillering of winter wheat. A. E. Grantham. Del. Sta. Bul. 117. 1917.
(37) Del. Sta. Bul. 129 (Rpt. 1921), p. 30. 1921.
(38) Some observations on the occurrence of sterile spikelets in wheat. A. E. Grantham. Jour. Agr. Research [U. S.], 6 (1916), No. 6, pp. 235–250.
(39) Fla. Sta. Rpt. 1910, pp. lxxix–xci.
(40) Fla. Sta. Rpt. 1911, pp. lxxxii–civ.
(41) Fla. Sta. Rpt. 1912, pp. cvx–cxxvi.
(42) Fla. Sta. Rpt. 1913, pp. civ–cxxx.
(43) Fla. Sta. Rpt. 1914, pp. lxxxi–cv.
(44) Fla. Sta. Rpt. 1915, pp. cvii–cxxix.
(45) A study of semisterility. J. Belling. Jour. Heredity, 5 (1914), No. 2, pp. 65–73.
(46) Mendelian inheritance in cotton hybrids. C. A. McLendon. Ga. Sta. Bul. 99. 1912.
(47) Cotton varieties in Georgia.—Variation of the oil content of cottonseed and resistance to disease. L. E. Rast. Ga. State Col. Agr., Bul. 121. 1917.
(48) Guam Sta. Rpt. 1920, pp. 36–39.
(49) Hawaii Univ. Quart. Bul. 3 (1924), No. 1, pp. 38–40.
(50) Hawaii Sta. Rpt. 1921, p. 28.
(51) Type and variability in corn. E. Davenport and H. L. Rietz. Ill. Sta. Bul. 119. 1907.
(52) Ten generations of corn breeding. L. H. Smith. Ill. Sta. Bul. 128. 1908.
(53) The effect of selection upon certain physical characters in the corn plant. L. H. Smith. Ill. Sta. Bul. 132. 1909.
(54) Corn varieties for chinch bug infested areas. W. P. Flint and J. C. Hackleman. Ill. Sta. Bul. 243, 1923.
(55) Ill. Sta. Rpt. 1922, pp. 15, 16.
(56) Aphis immunity of teosinte-corn hybrids. W. B. Gernert. Science, n. ser., 46 (1917), No. 1190, pp. 390–392.
(57) Results of corn disease investigations. G. N. Hoffer and J. R. Holbert. Science, n. ser., 47 (1918), No. 1210, pp. 246, 247.
(58) Chinch-bug resistance shown by certain varieties of corn. W. P. Flint. Jour. Econ. Ent., 14 (1921), No. 1, pp. 83–85.
(59) Anchorage and extent of corn root systems. J. R. Holbert and B. Koehler. Jour. Agr. Research [U. S.], 27 (1924), No. 2, pp. 71–78.
(60) Ind. Sta. Rpt. 1919, p. 63.
(61) Resistance in rye to leaf rust, *Puccinia dispersa.* E. B. Mains and C. E. Leighty. Jour. Agr. Research [U. S.], 25 (1923), No. 5, pp. 243–252.
(62) Breeding crop plants. H. K. Hayes and R. J. Garber. New York and London: McGraw-Hill Book Co., Inc., 1921, p. 131.
(63) Heritable characters of maize.—XIII, Endosperm defects—sweet defective and flint defective. E. W. Lindstrom. Jour. Heredity, 14 (1923), No. 3, pp. 126–135.
(64) Heritable characters of maize.—XVIII, Miniature germ. J. B. Wentz. Jour. Heredity, 15 (1924). No. 6, pp. 269–272.
(65) Hybrid vigor in soy beans. J. B. Wentz and R. T. Stewart. Jour. Amer. Soc. Agron., 16 (1924), No. 8, pp. 534–540.

(66) Alfalfa breeding: Materials and methods. H. F. Roberts and G. F. Freeman. Kans. Sta. Bul. 151. 1907.
(67) Kans. Sta. Rpt. 1917, p. 23.
(68) Kans. Sta. Rpt. 1918, p. 26.
(69) Kans. Sta. Rpt. 1919, p. 30.
(70) The relation of ear characters of corn to yield. C. C. Cunningham. Jour. Amer. Soc. Agron., 8 (1916), No. 3, pp. 188–196.
(70a) Development of the pistillate spikelet and fertilization in *Zea mays* L. E. C. Miller. Jour. Agr. Research [U. S.], 18 (1919), No. 5, pp. 255–265.
(71) The resistance of Kanred (P762), P1066, and P1068, three hard winter wheats, to leaf rust. L. E. Melchers and J. H. Parker. Abs. in Phytopathology, 10 (1920), No. 1, pp. 52, 53.
(72) Study of the relation of the length of kernel to the yield of corn (*Zea mays indentata*). C. C. Cunningham. Jour. Agr. Research [U. S.], 21 (1921), No. 7, pp. 427–438.
(73) Relation of hardness and other factors to protein content of wheat. H. F. Roberts. Jour. Agr. Research [U. S.], 21 (1921), No. 8, pp. 507–522.
(74) Self-fertility in red clover. E. N. Fergus. Ky. Sta. Circ. 29. 1922.
(75) Sugar cane seedlings. H. P. Agee. La. Stas. Bul. 127. 1911.
(76) La. Stas. Rpt. 1920, p. 17.
(77) Studies on oat breeding.—I, Variety tests, 1910–1913. F. M. Surface and C. W. Barber. Me. Sta. Bul. 229. 1914.
(78) Growth and variation in maize. R. Pearl and F. M. Surface. Natl. Acad. Sci. Proc., 1 (1915), No. 4, pp. 222–226; abs. in Me. Sta. Bul. 234, pp. 290, 291. 1914.
(79) Studies on oat breeding.—II, Selection within pure lines. F. M. Surface and R. Pearl. Me. Sta. Bul. 235. 1915.
(80) Studies on oat breeding.—IV, Pure line varieties. F. M. Surface and J. Zinn. Me. Sta. Bul. 250. 1916.
(81) On variation in Tartary buckwheat, *Fagopyrum tataricum* (L). Gaertn. J. Zinn. Genetics, 4(1919), No. 6, pp. 534–586; abs. in Me. Sta. Bul. 284, pp. 296–298. 1919.
(82) Wheat investigations.—I, Pure lines. J. Zinn. Me. Sta. Bul. 285. 1920.
(83) Sterility in wheat hybrids. K. Sax. Genetics, 6 (1921), No. 4, pp. 399–416; abs. in Me. Sta. Bul. 304, pp. 345–347. 1921.
(84) Wheat investigations.—II, Correlations between various characters of wheat and flour as determined from published data from chemical, milling, and baking tests of a number of American wheats. J. Zinn. Abs. in Me. Sta. Bul. 304, pp. 351, 352. 1921.
(85) Sterility in wheat hybrids.—II, Chromosome behavior in partially sterile hybrids. K. Sax. Genetics, 7 (1922), No. 6, pp. 513–552; abs. in Me. Sta. Bul. 309, pp. 93–95. 1922.
(86) Sterility in wheat hybrids.—III, Endosperm development and F_2 sterility. K. Sax. Genetics, 7 (1922), No. 6, pp. 553–558; abs. in Me. Sta. Bul. 309, pp. 95, 96. 1922.
(87) Studies on oat breeding.—III, On the inheritance of certain glume characters in the cross *Avena fatua* × *A. Sativa*. F. M. Surface. Genetics, 1 (1916), No. 3, pp. 252–286.
(88) Studies on oat breeding.—V, The F_1 and F_2 generations on a cross between a naked and a hulled oat. J. Zinn and F. M. Surface. Jour. Agr. Research [U. S.], 10 (1917), No. 6, pp. 293–312.
(89) Chromosome relationships in wheat. K. Sax. Science, n. ser., 54 (1921), No. 1400, pp. 413–415.
(90) A genetic and cytological study of certain hybrids of wheat species. K. Sax and E. F. Gaines. Jour. Agr. Research [U. S.], 28 (1924), No. 10, pp. 1017–1032.
(91) Fertilizing and cultural experiments with Irish potatoes. T. H. White. Md. Sta. Bul. 215. 1918.
(92) Mass. Sta. Rpt. 1909, pt. 1, pp. 168–175.
(93) Rust-resisting sunflowers. F. A. Spragg and E. E. Down. Mich. Sta. Quart. Bul., vol. 2, No. 3, pp. 128, 129. 1920.
(94) The effect of selection in pure-line oat work. F. A. Spragg. Proc. Amer. Soc. Agron., 4 (1912), pp. 81–83.
(95) Barley investigations. C. P. Bull. Minn. Sta. Bul. 148. 1915.
(96) Ear-type selection and yield in corn. P. J. Olson, C. P. Bull, and H. K. Hayes. Minn. Sta. Bul. 174. 1918.
(96a) Methods of corn breeding. H. K. Hayes and L. Alexander. Minn. Sta. Bul. 210. 1924.
(97) Inheritance and yield with particular reference to rust resistance and panicle type in oats. R. J. Garber. Minn. Sta. Tech. Bul. 7. 1922.
(98) Minn. Sta. Rpt. 1921, p. 45.
(99) Minn. Sta. Rpt. 1921, p. 46.
(100) Minn. Sta. Rpt. 1921, p. 66.
(101) Minn. Sta. Rpt. 1922, p. 52.
(102) Minn. Sta. Rpt. 1922, p. 97.
(103) Minn. Sta. Rpt. 1922, pp. 98, 99.
(104) The inheritance of the length of internode in the rachis of the barley spike. H. K. Hayes and H. V. Harlan. U. S. Dept. Agr. Bul. 869. 1920.
(105) Inheritance of a mosaic pericarp pattern color of maize. H. K. Hayes. Genetics, 2 (1917), No. 3, pp. 261–281.
(106) Normal self-fertilization in corn. H. K. Hayes. Jour. Amer. Soc. Agron., 10 (1918), No. 3, pp. 123–126.
(107) Natural crossing in wheat. H. K. Hayes. Jour. Heredity, 9 (1918), No. 7, pp. 326–330, 334.
(108) A study of the relation of some morphological characters to lodging in cereals. R. J. Garber and P. J. Olson. Jour. Amer. Soc. Agron., 11 (1919), No. 5, pp. 173–186.
(109) On the blooming and fertilization of wheat flowers. C. E. Leighty and T. B. Hutcheson. Jour. Amer. Soc. Agron., 11 (1919), No. 4, pp. 143–162.
(110) The uselessness of hill selection under conditions where rapid degeneration or "running out" is prevalent. R. Wellington. Amer. Soc. Hort. Sci. Proc., 16 (1919), pp. 175–179.

(111) Occurrence of the fixed intermediate, *Hordeum intermedium haxtoni*, in crosses between *H. vulgare pallidum* and *H. distichon palmella*. H. V. Harlan and H. K. Hayes. Jour. Agr. Research [U. S.], 19 (1920), No. 11, pp. 575–591.
(112) Genetics of rust resistance in crosses of varieties of *Triticum vulgare* with varieties of *T. durum* and *T. dicoccum*. H. K. Hayes, J. H. Parker, and C. Kurtzweil. Jour. Agr. Research [U. S.], 19 (1920), No. 11, pp. 523–542.
(113) Comparative vigor of F_1 wheat crosses and their parents. F. Griffee. Jour. Agr. Research [U. S.], 22 (1921), No. 2, pp. 53–63.
(114) The effects of self-fertilization in timothy. H. K. Hayes and H. D. Barker. Jour. Amer. Soc. Agron., 14 (1922), No. 8, pp. 289–293.
(115) The application of genetic principles to potato breeding. F. A. Krantz. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 124–129.
(116) Inheritance of kernel and spike characters in crosses between varieties of *Triticum vulgare*. H. K. Hayes. Minn. Univ. Studies Biol. Sci., No. 4 (1923), pp. 163–183.
(117) Correlation of wheat kernel plumpness and protein content. C. H. Bailey and J. Hendel. Jour. Amer. Soc. Agron., 15 (1923), No. 9, pp. 345–350.
(118) Permanence of variety in the potato. F. A. Krantz. Jour. Agr. Research [U. S.], 23 (1923), No. 12, pp. 947–962.
(119) The inheritance of growth habit and resistance to stem rust in a cross between two varieties of common wheat. O. S. Aamodt. Jour. Agr. Research [U. S.], 24 (1923), No. 6, pp. 457–470.
(120) The mode of inheritance of resistance to *Puccinia graminis* with relation to seed color in crosses between varieties of durum wheat. J. B. Harrington and O. S. Aamodt. Jour. Agr. Research [U. S.], 24 (1923), No. 12, pp. 979–996.
(121) Cotton experiments, 1916. Miss. Sta. Bul. 178. 1916.
(122) Corn experiments. H. B. Brown. Miss. Sta. Bul. 197. 1921.
(123) A study of certain environmental factors and varietal differences influencing the fruiting of cotton. E. C. Ewing. Miss. Sta. Tech. Bul. 8. 1918.
(124) Mo. Sta. Bul. 197 (Rpt. 1922), p. 69.
(125) Characters connected with the yield of the corn plant. W. C. Etheridge. Mo. Sta. Research Bul. 46. 1921.
(126) Scarred endosperm and size inheritance in kernels of maize. W. H. Eyster. Mo. Sta. Research Bul. 52. 1922.
(127) A primitive sporophyte in maize. W. H. Eyster. Amer. Jour. Bot., 11 (1924), No. 1, pp. 7–14.
(128) A second factor for primitive sporophyte in maize. W. H. Eyster. Amer. Nat., 58 (1924), No. 658, pp. 436–439.
(129) Mont. Sta. Rpt. 1920, pp. 20, 21.
(130) Mont. Sta. Rpt. 1922, pp. 23, 24.
(131) Correlation between depth of eyes and degeneration among potatoes. O. B. Whipple. Amer. Soc. Hort. Sci. Proc., 16 (1919), pp. 181–183.
(132) Line selection work with potatoes. O. B. Whipple. Jour. Agr. Research [U. S.], 19 (1920), No. 11, pp. 543–573.
(133) The inheritance of quantitative characters in maize. R. A. Emerson and E. M. East. Nebr. Sta. Research Bul. 2. 1913.
(134) The inheritance of a recurring somatic variation in variegated ears of maize. R. A. Emerson. Nebr. Sta. Research Bul. 4. 1914.
(135) Corn investigations. T. A. Kiesselbach. Nebr. Sta. Research Bul. 20. 1922.
(136) Nebr. Sta. Rpt. 1910, pp. 58–90.
(137) Nebr. Sta. Rpt. 1910, pp. 108–159.
(138) Nebr. Sta. Rpt. 1911, pp. 81–88.
(139) Nebr. Sta. Rpt. 1914, p. ix.
(140) Nebr. Sta. Rpt. 1920, p. 13.
(141) Nebr. Sta. Rpt. 1923, p. 13.
(142) A genetic and cytological study of certain types of albinism in maize. F. C. Miles. Jour. Genetics, 4 (1915), No. 3, pp. 193–214.
(143) N. J. Stas. Rpt. 1909, p. 270.
(144) N. J. Stas. Rpt. 1911, p. 331.
(145) N. J. Stas. Rpt. 1913, pp. 539–541.
(146) N. J. Stas. Rpt. 1915, pp. 262–264.
(147) N. J. Stas. Rpt. 1916, p. 437.
(148) Variation and correlation in timothy. C. F. Clark. N. Y. Cornell Sta. Bul. 279. 1910.
(149) Correlation of characters in corn. E. C. Ewing. N. Y. Cornell Sta. Bul. 287. 1910.
(150) The production of new and improved varieties of timothy. H. H. Webber et al. N. Y. Cornell Sta. Bul. 313. 1912.
(151) Oats for New York. H. H. Love. N. Y. Cornell Sta. Bul. 343. 1914.
(152) Variation and correlation of oats (*Avena sativa*).—I, Studies showing the effect of seasonal changes on biometrical constants. H. H. Love and C. E. Leighty. N. Y. Cornell Sta. Mem. 3. 1914.
(153) Variation and correlation of oats (*Avena sativa*.)—II, Effect of differences in environment, varieties, and methods on biometrical constants. C. E. Leighty. N. Y. Cornell Sta. Mem. 4. 1914.
(154) Chlorophyll inheritance in maize. E. W. Lindstrom. N. Y. Cornell Sta. Mem. 13. 1918.
(155) The inheritance of the weak awn in certain Avena crosses and its relation to other characters of the oat grain. A. C. Fraser. N. Y. Cornell Sta. Mem. 23. 1919.
(156) The genetic relations of plant colors in maize. R. A. Emerson. N. Y. Cornell Sta. Mem. 39. 1921.
(157) The inheritance of salmon silk color in maize. E. G. Anderson. N. Y. Cornell Sta. Mem. 48. 1921.
(158) The genetics of square-headedness and of density in wheat, and the relation of these to other characters. S. Boshnakian. N. Y. Cornell Sta. Mem. 53. 1922.
(159) The linkage of certain aleurone and endosperm factors in maize, and their relation to other linkage groups. C. B. Hutchison. N. Y. Cornell Sta. Mem. 60. 1922.
(160) The morphology of the double kernel in *Zea mays* var. *polysperma*. M. E. Stratton. N. Y. Cornell Sta. Mem. 69. 1923.
(161) The inheritance of blotch leaf in maize. R. A. Emerson. N. Y. Cornell Sta. Mem. 70. 1923.

(162) The inheritance of a lethal pale green seedling character in maize. A. M. Brunson. N. Y. Cornell Sta. Mem. 72. 1924.
(163) The comparisons of yield between hybrids and selections in oats. H. H. Love. Amer. Breeders Mag., 3 (1912), No. 4, pp. 289–292.
(164) Linkage in maize: Aleurone and chlorophyll factors. E. W. Lindstrom. Amer. Nat., 51 (1917), No. 604, pp. 225–237.
(165) Correlations between ear characters and yield in corn. H. H. Love and J. B. Wentz. Jour. Amer. Soc. Agron., 9 (1917), No. 7, pp. 315–322.
(166) Linkage in maize: The C aleurone factor and waxy endosperm. T. Bregger. Amer. Nat., 52 (1918), No. 613, pp. 57–61.
(167) The inheritance of hull-lessness in oat hybrids. H. H. Love and G. P. McRostie. Amer. Nat., 53 (1919), No. 624, pp. 5–32.
(168) A preliminary study of the inheritance of rust resistance in oats. J. H. Parker. Jour. Amer. Soc. Agron., 12 (1920), No. 1, pp. 23–38.
(169) Heritable characters of maize.—II, Pistillate flowered maize plants. R. A. Emerson. Jour. Heredity, 11, (1920), No. 2, pp. 65–76.
(170) Genetic behavior of the spelt form in crosses between *Triticum spelta* and *T. sativum*. C. E. Leighty and S. Boshnakian Jour. Agr. Research [U. S.], 22 (1921), No. 7, pp. 335–364.
(171) Cytology of chlorophyll types of maize. L. F. Randolph. Bot. Gaz., 73 (1922), No. 5, pp. 337–375.
(172) The inheritance of the spring and winter growing habit in crosses between typical spring and typical winter wheats, and the response of wheat plants to artificial light H. P. Cooper. Jour. Amer. Soc. Agron., 15 (1923), No. 1, pp. 15–25.
(173) The relation of the spelt factor in wheat to rachis internode characters. S. Boshnakian. Genetics, 8 (1923), No. 3, pp. 261–275.
(174) The inheritance of smut resistance in crosses of certain varieties of oats. A. F. Barney. Jour. Amer. Soc. Agron., 16 (1924), No. 4, pp. 283–291.
(175) N. C. Sta. Rpt. 1919, p. 38.
(176) N. C. Sta. Rpt. 1920, p. 29.
(177) The inheritance of rust resistance in a family derived from a cross between durum and common wheat. L. R. Waldron. N. Dak. Sta. Bul. 147. 1921.
(178) Some physical and chemical studies of certain clones and sibs of brome grass. L. R. Waldron. N. Dak. Sta. Bul. 152. 1921.
(179) N. Dak. Sta. Bul. 159 (Rpt. 1921), p. 23. 1922.
(180) Effect of first generation hybrids upon yield of corn. L. R. Waldron. N. Dak. Sta. Bul. 177. 1924.
(181) A study of dwarfness in wheat accompanied by unexpected ratios. L. R. Waldron. Genetics, 9 (1924), No. 3, pp. 212–246.
(182) Tobacco: Breeding cigar filler in Ohio. A. D. Selby and T. Houser. Ohio Sta. Bul. 239. 1912.
(183) Ear characters not correlated with yield in corn. A. G. McCall and C. Wheeler. Jour. Amer. Soc. Agron., 5 (1913), No. 2, pp. 117, 118.
(184) Variation in pure lines of winter wheat. C. G. Williams. Soc. Prom. Agr. Sci. Proc., 35 (1914), pp. 89–94.
(185) Oreg. Sta. Bien. Rpt. 1921–22, p. 44.
(186) Experiments with corn. C. F. Noll. Pa. Sta. Bul. 139. 1916.
(187) Pa. Sta. Rpt. 1916, pp. 455–471.
(188) Pa. Sta. Bul. 170 (Rpt. 1920–21), p. 9. 1922.
(189) Pa. Sta. Bul. 170 (Rpt. 1920–21), pp. 19, 20. 1922.
(190) Pennsylvania Station. Experiment Station Record, 46, p. 397. 1922.
(191) The reaction of first generation hybrid potatoes to the wart disease. C. R. Orton and F. Weiss. Phytopathology, 11 (1921), No. 8, pp. 306–310.
(192) P. R. Sta. Rpt. 1921, pp. 16–18.
(193) P. R. Sta. Rpt. 1922, p. 5.
(194) P. R. Sta. Rpt. 1923, p. 9.
(195) P. R. Dept. Agr. Sta. Rpt. 1917, pp 16–19.
(196) Studies in inheritance in sugar cane. H. B. Cowgill. Jour. Dept. Agr. P. R., 2 (1918), No. 1, pp. 33–41.
(197) Gumming disease of sugar cane. J. Matz. Jour. Dept. Agr. and Labor Porto Rico, 6 (1922), No. 3, pp. 5–21.
(198) Some phases of breeding work and seed production of Irish potatoes. W. J. Young. S. C. Sta. Bul. 210. 1922.
(199) S. C. Sta. Rpt. 1918, p. 20.
(200) Sugar-beet culture in South Dakota. J. H. Shepard. S. Dak. Sta. Bul. 142. 1913.
(201) The influence of length of wheat heads on resulting crops. A. N. Hume, M. Champlin, and M. Fowlds. S. Dak. Sta. Bul. 187. 1919.
(202) S. Dak. Sta. Rpt. 1913, pp. 24–27.
(203) S. Dak. Sta. Rpt. 1923, pp. 11, 12.
(204) Researches on disease resistance in red clover: Preliminary report. S. M. Bain. Tenn. Acad. Sci. Trans., 2 (1914–1917), p. 85.
(205) Type and variability in kafir. A. B. Conner and R. E. Karper. Tex. Sta. Bul. 279. 1921.
(206) Tex. Sta. Rpt. 1919, p. 14.
(207) Tex. Sta. Rpt. 1921, p. 36.
(208) Natural cross-pollination in milo. R. E. Karper and A. B. Conner. Jour. Amer. Soc. Agron., 11 (1919), No. 6, pp. 257–259.
(209) Improvement of sorghums by hybridization. H. B. Vinall and A. B. Cron. Jour. Heredity, 12 (1921), No. 10, pp. 435–443.
(210) The inheritance of seed coat color in certain crosses in grain sorghum. A. B. Conner and R. E. Karper. Jour. Amer. Soc. Agron., 15 (1923), No. 8, pp. 338–344.
(211) Inbreeding grain sorghum. A. B. Conner and R. E. Karper. Jour. Heredity, 15 (1924), No. 7, pp. 299–302.
(212) Potato improvement by hill selection. G. Stewart. Utah Sta. Bul. 176. 1920.
(213) The effect of hybridization on maturity and yield in corn. T. B. Hutcheson and T. K. Wolfe. Va. Sta. Tech. Bul. 18. 1917.

(214) A biometrical analysis of characters of maize and of their inheritance. T. K. Wolfe. Va. Sta. Tech. Bul. 26. 1924.
(215) Va. Sta. Rpts. 1915-16, pp. 193-199.
(216) Relation between yield and ear characters in corn. T. B. Hutcheson and T. K. Wolfe. Jour. Amer. Soc. Agron., 10 (1918), No. 6, pp. 250-255.
(217) Correlation between certain characters of the Green Mountain Irish potato. T. K. Wolfe. Jour. Amer. Soc. Agron., 15 (1923), No. 11, pp. 467-470.
(218) The correlation between time of germination, maturity, and yield of corn. T. B. Hutcheson and T. K. Wolfe. Jour. Amer. Soc. Agron. 16 (1924), No. 8, pp. 483-485.
(219) V. I. Sta. Rpt. 1920, pp. 7-14.
(220) A report of the investigations concerning the chemical composition of wheat, 1906 to 1912, inclusive. R. W. Thatcher. Wash. Sta. Bul. 111. 1913.
(221) Inheritance in wheat, barley, and oat hybrids. E. F. Gaines. Wash. Sta. Bul. 135. 1917.
(222) Studies on the morphology of wheat. G. H. Jensen. Wash. Sta. Bul. 150. 1918.
(223) Wash. Sta. Bul. 155 (Rpt. 1919), p. 28. 1920.
(224) Markton, an oat variety immune from covered smut. T. R. Stanton, D. E. Stephens, and E. F. Gaines. U. S. Dept. Agr., Dept. Circ. 324. 1924.
(225) The inheritance of resistance to bunt or stinking smut of wheat. E. F. Gaines. Jour. Amer. Soc. Agron., 12 (1920), No. 4, pp. 124-132.
(226) A study of hybrid oats, *Avena sterilis* × *A. orientalis*. S. Wakabayashi. Jour. Amer. Soc. Agron., 13 (1921), No. 6-7, pp. 259-266.
(227) Natural crossing in winter wheat. R. J. Garber and K. S. Quesenberry. Jour. Amer. Soc. Agron., 15 (1923), No. 12, pp. 508-512.
(228) Another instance of defective endosperm in maize. R. J. Garber and B. L. Wade. Jour. Heredity, 15 (1924), No. 2, pp. 69-71.
(229) The improvement of Wisconsin tobacco through seed selection. E. P. Sandsten. Wis. Sta. Bul. 176. 1909.
(230) Wis. Sta. Bul. 275 (Rpt. 1916), pp. 36, 37. 1917.
(231) Wis. Sta. Bul. 302 (Rpts. 1917-1918), p. 27. 1919.
(232) Wis. Sta. Bul. 323 (Rpt. 1920), p. 29. 1920.
(233) Wis. Sta. Bul 339 (Rpt. 1921), pp. 113, 114. 1922.
(234) Wis. Sta. Bul. 339 (Rpt. 1921), pp. 115, 116. 1922.
(235) Inheritance of branching habit in tobacco. J. Johnson. Genetics, 4 (1919), No. 4, pp. 307-340.
(236) Inheritance of disease resistance to *Thielavia basicola*. J. Johnson. Abs. in Phytopathology, 11 (1921), No. 1, p. 49.
(237) The extent of natural cross-pollination in soy beans. C. M. Woodworth. Jour. Amer. Soc. Agron., 14 (1922), No. 7, pp. 278-283.
(238) Inheritance of growth habit, pod color, and flower color in soy beans. C. W. Woodworth. Jour. Amer. Soc. Agron., 15 (1923), No. 12, pp. 481-495.
(239) Potato breeding and selection. W. Stuart. U. S. Dept. Agr. Bul. 195. 1915.

STATION WORK IN HORTICULTURAL BREEDING

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A review of the fruit breeding activities of the agricultural experiment stations shows the tremendous awakening of interest coincident with the rediscovery of Mendel's law at the beginning of the present century (1).[7] Knowledge of the art of breeding had been accumulating for years, but no definite end beyond the development of improved varieties had been attained until light was received from the work of Mendel. Science, grasping the significance of his fundamental theory, took up the art of breeding and began to develop it slowly but surely into systematic knowledge. Progress has been necessarily slow because of the many fundamental features needing solution before real breeding work could be undertaken. Technique had to be developed and a knowledge of material obtained. Nevertheless, results have been secured that are not only valuable in themselves but point to much greater advances in the future.

MENDELIAN STUDIES

The discovery in 1901 of the real significance of Mendel's studies in inheritance, culminating in his theory of dominance and recessiveness and segregation and recombination of unit characters, had a far-reaching and very stimulating effect on breeding work in horticulture at the agricultural experiment stations. Up to this time most of the fruit and vegetable breeding projects were conducted by private individuals, whose single aim was the development of improved varieties. Mendel's hypothesis changed plant breeding from an art to a science. Nevertheless, the work of practical horticultural breeders (Bull, Campbell, Munson, Hovey, Stayman, and others) really constituted the foundation for the later progress and yielded many of the most profitable varieties of fruit.

Progress in the development of fundamental principles underlying the breeding of fruit and vegetables has been greatly handicapped by the heterozygous nature and long life of much of the material available for study. With the exception of certain vegetables naturally self-pollinating or capable of reproduction by self-pollination, progress has been necessarily slow. The Nebraska station (29), working with inheritance of characters, height, flower color, and seed color in the bean, was one of the first to report on the results of breeding work in the light of Mendel's discovery. The Virginia station (64), reporting upon tomato breeding studies, concluded that segregation and recombination occurred in accordance with Mendel's law, a declaration confirmed by work at the New York Cornell station (35) and by the New York State station (44). Comprehensive studies in tomato breeding were also carried on by the New Jersey stations (31). The Vermont station (57) found that Mendel's law held for the segregation of flower type in the carnation, and the New Hampshire station (30), working with the muskmelon, reached similar conclusions in regard to form and size of fruit, color, and netting of skin.

Records made in extensive fruit breeding operations at the New York State station have been summarized for several fruits. The apple breeding studies (38) indicated the difficulty of establishing inheritance laws for the fruit because of the blending, linkage, and existence of latent characters. Experiments with grapes (45) showed that selfing results in a loss of vigor in the seedlings. Crosses, on the other hand, yielded an unexpected proportion of poor quality seedlings. White, the only skin color found pure, was recessive to black and red. Investigations with raspberries (39) showed that purple-fruited berries are hybrids between the black and the red-fruited forms. As a result of studies of the inheritance of sex in strawberries (40), it was found that the crossing of perfect varieties yielded practically all perfect progeny, while crossing imperfect and perfect sorts yielded seedlings in the proportion of 1 : 1.

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[7] Numbers in parentheses refer to references, p. 64.

The Iowa station (18) has carried on extensive breeding work with apples and pears in an attempt to breed hardy varieties. The North Carolina station (47) found that the fruit color in the Muscadine grape segregates according to the Mendelian ratio, white being pure and recessive to dark colors. This station also pointed out (49) that the floral types in *Vitis rotundifolia* are transmitted in definite Mendelian ratios. Recent studies at the New Jersey stations (32) suggest that the various types of foliar glands in the peach are inherited as Mendelian units. Extensive breeding work with apples and crab apples at the Illinois station has been reported upon at frequent intervals (16).

PURE LINE STUDIES

The Johannsen theory that ordinary commercial varieties of self-fertilized plants are made up of a number of pure, constant lines which once isolated can not be further improved by selection (2) has been utilized in breeding work by the stations, particularly in the isolation of high-yielding, vigorous strains of vegetables. The Pennsylvania station found large variations in the yielding capacities of cabbage (54) and tomato (55) of a single variety obtained from different seedsmen. Similar results were obtained by the Indiana station (17) and by the Virginia truck station (66). The Vermont station (58) and the Minnesota station (28) showed that the Hubbard squash, an important commercial variety, is ordinarily comprised of numerous component strains of differing fruit shapes, productivity, etc., that can be separated and perpetuated by self-pollination. The isolation of pure lines of Alaska pea was successfully accomplished at the Minnesota station (26).

STERILITY STUDIES

Previous to the rediscovery of Mendel's work, several of the American experiment stations were busily engaged in determining the pollinating capacities of many of the fruits. The importance of such knowledge was indicated in the failure of earlier horticulturists to recognize unisexuality in the strawberry, the existence of which led to many failures until the problem was finally solved in the slow and hard school of experience.

One of the first fruits to be studied in respect to sterility was the grape, the New York State station (43) and the Minnesota station (22) reporting at about the same time that many varieties are partially or fully sterile. Work at the Georgia station (14) helped to confirm these conclusions. The North Carolina station (46) reported that a large proportion of the Muscadine grape varieties are self-sterile.

That self-sterility is the rule in American plum species was indicated by work at the Vermont station (59, 60) and by the Wisconsin station (70). Work with the European plums at the Oregon station (52) and at the California station (4) showed that self-fertility is much more prevalent in this than in the American group.

Sterility studies with the apple, reported by many different stations, Vermont (62), Delaware (7, 9), Oregon (50), Minnesota (27), Maine (20), and Maryland (21), showed a surprising number of sterile or partially sterile varieties. The Delaware station (6, 8), the Virginia station (65), and more recently the California station (5) have reported upon work with pear varieties. Cherry varieties were studied at the Oregon station (51) and the New York State station (42). One fruit, the peach, was found largely self-fertile (10) until recent work at the New Jersey stations (34) indicated that there are exceptions, for example, the J. H. Hale variety.

Sterility observations have not been confined to fruits, studies of the almond being reported by the California station (3), of the filbert by the Oregon station (53), and of the pecan by the Georgia station (12).

CAUSES OF STERILITY

Not satisfied with the discovery of the existence of sterility in fruits, investigators have strenuously sought to determine the fundamental causes of failure to set fruit.

The Wisconsin station (72) studied the effects of humidity and temperature on the development of pollen grains. The New York State station (36) showed that the pollen of self-sterile grapes was incapable of growth in favorable media. Cytological studies at the Minnesota station (23) indicated that pollen sterility in the grape probably results from degeneration processes in the generative nuclei. At the North Carolina station (46) it was found that Muscadine grape varieties having reflexed stamens bore anthers containing defective pollen and required the presence of male

vines for pollination. The New York State station (41) pointed out that all grades of sex development exist in the cultivated grape, ranging from complete maleness to complete femaleness. An attempt by the Georgia station (13) to determine the underlying causes of self-sterility in *Vitis rotundifolia* confirmed the Minnesota conclusions (23), namely, that pollen of sterile vines develops normally for a time, until a degeneration occurs in generative nuclei.

Working with American species of plums, the Minnesota station (25) reported that sterility and cross-sterility are not due to pollen abortion but to the failure of the pollen tube to grow rapidly enough to insure the fusion of the gametes. Slow pollen tube development was observed in the Rome apple, at the West Virginia station (68). Sterility of the J. H. Hale peach was found by the New Jersey stations (33) to be due to the failure of the variety to develop viable pollen. Studies at the Minnesota station of the sexual condition in the strawberry (24) revealed no physiological sterility. The discovery of sterile pistils in some of the later flowers on an inflorescence was believed due to the diœcious ancestry of this fruit.

Working with wild species of Rubus, the Vermont station (63) reported that all species are either completely or nearly self-sterile, sterility in the blackberry being due to defective pollen. Self-sterility, discovered by the North Carolina station to be a common occurrence in the dewberry (48), was believed due to *Rubus trivialis* ancestry, the tendency to self-sterility being apparently transmitted not only to pure but to hybrid progeny. That hybridity is often a cause of sterility in fruits was early pointed out by the Vermont station (61). Various station investigators have observed that self-incompatibility, or the failure of the flower to set fruit in the presence of healthy pistils and viable pollen, is a frequent cause of self-sterility. The Wisconsin station (69) observed that trees exhausted by overbearing, drought, or soil poverty had a marked tendency to produce more defective pistils than normal trees. Cold and rainy weather during the blossoming season materially affects fruiting (37, 72).

BREEDING FOR DISEASE RESISTANCE

Studies at several of the stations have shown that susceptibility to disease in certain plants may be overcome, in part at least, by breeding.

The Virginia truck station (67) produced a mosaic-resistant spinach variety known as the Virginia Savoy by hybridizing the ordinary Savoy with a wild Manchurian form. The Wisconsin station (71), by continued selection under field conditions, has developed strains of cabbage resistant to yellows (*Fusarium conglutinans*). Work at the Georgia station (11) indicated that blossom-end rot resistance, observed in the cherry tomato, is transmitted to progeny of crosses with standard varieties. The Illinois (15), Louisiana (19), and Tennessee (56) stations reported satisfactory progress in the selection of tomato plants resistant to fusarium.

PRACTICAL RESULTS

Incidental to the accumulation of scientific material, many of the stations have made serious efforts to develop valuable varieties. Perhaps this work has been most highly developed at the New York State station, from which several very promising fruits have been disseminated, one of which, the Cortland apple, is already taking a prominent place in American pomology. The South Dakota, Minnesota, and Iowa stations have been successful in breeding fruits combining quality and ability to survive cold winters. Breeding work at the New Jersey stations has yielded several meritorious peaches, one of which is being disseminated under the name "Pioneer." Many of the other stations, Idaho, Maryland, etc., have large collections of promising apple, pear, grape, and other fruit seedlings under trial.

SUMMATION

The discovery of Mendel's law, De Vries's theory of mutation, and Johannsen's pure-line hypothesis opened a new era in the breeding of horticultural plants, the agricultural experiment stations being among the first institutions to realize the significance of these epoch-making concepts and to put into practice the ideas set forth. In the two decades that have elapsed fair progress has been attained, as indicated by the numerous publications upon the subject from various experiment stations. Much more rapid developments may be anticipated in the future because of increase in workers trained in plant breeding and associated subjects and because of the fact that much fundamental knowl-

edge is now at hand to serve as building material for the future.

REFERENCES

(1) Experiments in plant hybridisation. G. Mendel. Jour. Roy. Hort. Soc., 26 (1901), No. 1, pp. 1–32.
(2) Ueber Erblichkeit in Populationen und reinen Linien. W. Johannsen. Jena: G. Fischer, 1903, pp. 68.
(3) Almond pollination. W. P. Tufts. Calif. Sta. Bul. 306. 1919.
(4) Further experiments in plum pollination. A. H. Hendrickson. Calif. Sta. Bul. 352. 1922.
(5) Pear pollination. W. P. Tufts and G. L. Philp. Calif. Sta. Bul. 373. 1923.
(6) Kieffer pear pollinations. G. H. Powell. Del. Sta. Rpt. 1900, pp. 129–134.
(7) The pollination of apples.—Preliminary report. G. H. Powell. Del. Sta. Rpt. 1900, pp. 134–139.
(8) Pear self-pollination. C. P. Close. Del. Sta. Rpt. 1902, pp. 99, 100.
(9) Apple pollinations. C. P. Close. Del. Sta. Rpt. 1902, pp. 101, 102.
(10) Peach self-pollination. Del. Sta. Rpt. 1902, pp. 100, 101.
(11) Transmission of resistance and susceptibility to blossom-end rot in tomatoes. H. P. Stuckey. Ga. Sta. Bul. 121. 1916.
(12) The two groups of varieties of Hicora pecan and their relation to self-sterility. H. P. Stuckey. Ga. Sta. Bul. 124. 1916.
(13) Work with *Vitis rotundifolia,* a species of muscadine grape. H. P. Stuckey. Ga. Sta. Bul. 133. 1919.
(14) Grapes. Ga. Sta. Rpt. 1900, pp. 310–317.
(15) Tomato selection for fusarium resistance. C. E. Durst. Phytopathology, 8 (1918), p. 80.
(16) Oldenburg as female in apple crosses. C. S. Crandall. Amer. Soc. Hort. Sci. Proc., 20 (1923), pp. 13–19.
(17) Tomato investigations. J. G. Boyle and J. B. Abbott. Ind. Sta. Bul. 165. 1913.
(18) Fruit breeding investigations. Iowa Sta. Rpt. 1921, p. 44.
(19) A study of wilt resistance in the seed bed. C. W. Edgerton. Phytopathology, 8 (1918), pp. 5–14.
(20) Self-sterility and cross-sterility in the apple. J. W. Gowen. Me. Sta. Bul. 287. 1920.
(21) Apple pollen and pollination studies in Maryland. E. C. Auchter. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 51–80.
(22) Cross-fertilization of grapes. S. B. Green. Minn. Sta. Bul. 32. 1893.
(23) Pollen development in the grape, with special reference to sterility. M. J. Dorsey. Minn. Sta. Bul. 144. 1914.
(24) Sterility in the strawberry. W. D. Valleau. Jour. Agr. Research [U. S.], 12 (1918), No. 10, pp. 613–670.
(25) A study in sterility in the plum. M. J. Dorsey. Genetics, 4 (1919), pp. 417–488.
(26) Results of selection in the Alaska pea. J. W. Bushnell. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 41–47.
(27) The set of fruit in apple crosses. M. J. Dorsey. Amer. Soc. Hort. Sci. Proc., 18 (1921), pp. 82–94.
(28) Isolation of uniform types of Hubbard squash by inbreeding. J. W. Bushnell. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 139–144.
(29) Heredity in bean hybrids (*Phaseolus vulgaris*). R. A. Emerson. Nebr. Sta. Rpt. 1903, pp. 33–68.
(30) Mendelism in melons. D. Lumsden. N. H. Sta. Bul. 172. 1914.
(31) The F_1 heredity of size, shape, and number in tomato fruits. B. H. A. Groth. N. J. Stas. Bul. 242. 1912.
(32) Inheritance of foliar glands of the peach. C. H. Connors. Amer. Soc. Hort. Sci. Proc., 19 (1921), pp. 20–26.
(33) Peach breeding: A summary of results. C. H. Connors. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 108–115.
(34) Fruit setting on the J. H. Hale peach. C. H. Connors. Amer. Soc. Hort. Sci. Proc., 19 (1922), pp. 147–151.
(35) A Mendelian study of tomatoes. A. W. Gilbert. Amer. Breeders Assoc. Ann. Rpt. 1911, pp. 169–188.
(36) A study of grape pollen. N. O. Booth. N. Y. State Sta. Bul. 224. 1902.
(37) The relation of water to the setting of fruit, with blooming data for 866 varieties of fruit. U. P. Hedrick. N. Y. State Sta. Bul. 299. 1908.
(38) An experiment in breeding apples. U. P. Hedrick and R. Wellington. N. Y. State Sta. Bul. 350. 1912.
(39) Some notes on the breeding of raspberries. R. D. Anthony. N. Y. State Sta. Bul. 417. 1916.
(40) Inheritance of sex in strawberries. R. D. Anthony. N. Y. State Sta. Tech. Bul. 63. 1919.
(41) Types of flowers and intersexes in grapes with reference to fruit development. A. B. Stout. N. Y. State Sta. Tech. Bul. 82. 1921.
(42) Self-sterility and self-fertility of fruit varieties grown in New York. R. Wellington. N. Y. State Sta. Circ. 71. 1923.
(43) Notes on self-pollination of the grape. N. Y. State Sta. Rpt. 1892, pp. 597–606.
(44) Mendelian characters in tomatoes. U. P. Hedrick and N. O. Booth. Amer. Soc. Hort. Sci. Proc., 1907, pp. 19–24.
(45) Inheritance of certain characters of grapes. U. P. Hedrick and R. D. Anthony. Jour. Agr. Research [U. S.], 4 (1915), No. 4, pp. 315–330.
(46) Self-sterility of the scuppernong and other muscadine grapes. F. C. Reimer and L. R. Detjen. N. C. Sta. Bul. 209. 1910.
(47) Breeding Rotundifolia grapes: A study of transmission of character. F. C. Reimer and L. R. Detjen. N. C. Sta. Tech. Bul. 10. 1914.
(48) Self-sterility in the dewberries and blackberries. L. R. Detjen. N. C. Sta. Tech. Bul. 11. 1916.
(49) Inheritance of sex in *Vitis rotundifolia.* L. R. Detjen. N. C. Sta. Tech. Bul. 12. 1917.
(50) Pollination of the apple. C. L. Lewis and C. C. Vincent. Oreg. Sta. Bul. 104. 1909.
(51) A preliminary report on the pollination of sweet cherry. V. R. Gardner. Oreg. Sta. Bul. 116. 1913.
(52) Report of three years' results in plum pollination in Oregon. R. E. Marshall. Amer. Soc. Hort. Sci. Proc., 16 (1919), pp. 42–49.

(53) Pollination of filberts. C. E. Schuster. Oreg. Grower, 3 (1922), No. 6, pp. 3, 5, 9.
(54) Strain tests of cabbage. C. E. Myers. Pa. Sta. Bul. 119. 1912.
(55) Strain tests of tomatoes. C. E. Myers. Pa. Sta. Bul. 129. 1914.
(56) Notes on tomato diseases with results of selection for resistance. S. H. Essary. Tenn. Sta. Bul. 95 (1912).
(57) Mendelian inheritance in the carnation. W. Stuart. Vt. Sta. Bul. 163. 1912.
(58) Yield and quality in Hubbard squash. M. B. Cummings and W. C. Stone. Vt. Sta. Bul. 222. 1921.
(59) Problems in plum pollination. F. A. Waugh. Vt. Sta. Rpt. 1897, pp. 87–98.
(60) Problems in plum pollination. F. A. Waugh. Vt. Sta. Rpt. 1898, pp. 238–262.
(61) Malformation of blossoms. Vt. Sta. Rpt. 1900, pp. 358, 359.
(62) The pollination of apples. F. A. Waugh. Vt. Sta. Rpt. 1900, pp. 362–366.
(63) Blackberries of New England: Genetic status of the plants. A. K. Peiterson. Vt. Sta. Bul. 218. 1921.
(64) Inheritance in tomato hybrids. H. L. Price and A. W. Drinkard, jr. Va. Sta. Bul. 177. 1908.
(65) Pollination of Bartlett and Kieffer pears. S. W. Fletcher. Va. Sta. Rpt. 1909–10, pp. 213, 224.
(66) Cabbage strain tests. H. H. Zimmerley. Va. Truck Sta. Bul. 37–38. 1922.
(67) Notes on spinach breeding. L. B. Smith. Amer. Soc. Hort. Sci. Proc., 17 (1920), pp. 146–155.
(68) Physiological aspects of self-sterility of the apple. L. I. Knight. Amer. Soc. Hort. Sci. Proc., 1917, pp. 101–105.
(69) The culture of native plums in the Northwest. E. S. Goff. Wis. Sta. Bul. 63. 1897.
(70) Native plums. E. S. Goff. Wis. Sta. Bul. 87. 1901.
(71) The control of cabbage yellows through disease resistance. L. R. Jones and J. C. Gilman. Wis. Sta. Research Bul. 38. 1915.
(72) A study of certain conditions affecting the setting of fruits. E. S. Goff. Wis. Sta. Rpt. 1901, pp. 289–303.

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INVESTIGATIONS IN ANIMAL GENETICS AT THE EXPERIMENT STATIONS

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Since the rediscovery of the fundamentals of Mendel's law in 1900 by DeVries in Holland, Von Tschermak in Austria, and Correns in Germany, the increasing recognition accorded the results of genetic investigations has been gratifying. At first the practical application of Mendelism was not so clear with animals as with plants, but largely because of the early work of Bateson in England, Cuenot in France, and Castle and Davenport in America its application to animal breeding became apparent. The present knowledge of the behavior of characters in inheritance is, however, so incomplete that the animal geneticist can do little more than attempt to offer explanations for what has occurred in breeding operations.

Distinctly more progress has been made with plants than with animals, but the problem is very different. Characters of economic importance, such as conformation, fecundity, and milk production, are evidently inherited in a very complicated manner and it is furthermore impracticable to have the numbers for selection in animal breeding that are available to the cereal investigator for example, who may use for continued breeding only a few plants selected from the thousands produced. The impracticability of doing this with cattle is evident when we consider that one offspring annually is the best that can be expected from a selected female, and that only after she has reached two years of age. Considering this handicap, it must be admitted that the founders of our present breeds of livestock were surprisingly successful. Analyses by geneticists of the methods used by the early breeders have shown that, though they did not understand the present accepted laws, they followed closely the now recommended principles of breeding and understood in the main the results to be expected from various types of matings.

Research in animal genetics has only just begun. Investigations have been slow in furnishing results, not only because of the time required but because of lack of training of many of the investigators. Distinct progress has, however, been made, notwithstanding this handicap. Before the rediscovery of Mendel's paper, Weisman had already associated hereditary factors with the chromosomes, which seemed to be the only constant and conspicuous bodies carried by both the ova and spermatozoa. This hypothesis has not only been corroborated in the more recent work, but in the extensive studies with the pomace fly (*Drosophila melanogaster*) by T. H. Morgan and associates at Columbia University the theoretical location in the chromosome of the genes determining hundreds of characters has been effected. Furthermore, the phenomena associated with crossing over, nondisjunction, polyploidy, etc., have been clearly demonstrated in the laboratory with this fly. In so far as it has been possible to determine, the same principles are generally operating in the determination of characters in plants and animals.

Numerous publications on Mendelism in animals followed the early papers. The State agricultural experiment stations have contributed a large number of such papers, especially in more recent years, on the inheritance of characters in the domestic animals. The stations have had an advantage in this respect, since nearly all of them have herds of the various farm animals which are available for preliminary investigations at least. Furthermore, data are available in the form of herdbooks and records of milk production and egg-laying contests with which those working in agriculture are more familiar than geneticists at other institutions. The stations have perhaps not contributed so much toward the new and fundamental problems as might be expected, but since the greater part of this work has been done with the larger animals the explanation is obvious.

CHROMOSOME STUDIES

Studies of the chromosome numbers and behavior during gametogenesis require proficiency in technique, and few investigators have carried on

such work with the domestic animals, although it is the correlation of the theory with the actual cytological observations that has given added weight to the theoretical laws of heredity.

Cytological studies have been made at the Idaho experiment station with all of the more common domestic animals and the chromosome counts determined on at least one sex in each case. The horse has been found to produce sperms (21)[8] containing 19 and 17 chromosomes in approximately equal numbers, and it is assumed that the diploid number in females is 38. The ass has, however, 65 chromosomes (22). The mule thus results from the fertilization of a 19-chromosome ovum by a sperm carrying 32 or 33 chromosomes. In consequence, reduction divisions in the mule are abnormal and the pairing of the chromosomes during reduction was observed to be incomplete and inconstant, no normal sperms being formed. In the pig (20) the somatic cells of the male contained 18 and the female 20 chromosomes. Observations of spermatogenesis showed that the sperms formed contain 8 and 10 chromosomes in equal numbers.

The spermatogonia of adult bulls (23, 26) and the somatic tissue of male fetuses showed 37 chromosomes, with the odd chomosome (sex), which was larger, passing undivided to one pole at the first spermatocyte division. Two sex chromosomes were also observed in the oogonia of female embryos. In sheep (24) the spermatogonia and somatic cells of male embryos were found to contain 33 chromosomes, while the oogonia and somatic cells of females contained 34. The spermatocytes contained 16 and 17 chromosomes in equal numbers, while all ova contained 17 chromosomes. Measurements of the mature spermatozoa of the horse, pig, and sheep showed a definite dimorphism in the head length, while the ova were all of a similar type.

The large numbers of chromosomes in these animals give an indication of the difficulties involved in the location of the genes in the different chromosomes and of the establishment of linkage relations.

SIMPLE MENDELIAN INHERITANCE

The behavior of colors in crosses is so much more striking and easier to follow than other characters that much progress has been made in determining the genes responsible and their behavior, and in case of rats, mice, and rabbits linkage relations have been established with a few such characters. These results bear out the fundamental principle of the chromosome as the carrier of the genes in determining the mode of the inheritance.

The Wisconsin station made an analysis of the cause of red calves occurring as purebred offspring of the black breeds (358). It was found that some of the foundation animals in the Angus, Galloway, and Holstein breeds were red. It was pointed out that red is inherited as a simple recessive to black, and the occurrence of red animals meant that both sire and dam were heterozygous for this character. This station also determined in crosses between Jersey-Angus and Holstein-Angus cattle that the polled condition and black color were dominant (352, 353). Scurs appeared on some of the heterozygous polled individuals, especially in males.

Similar results in regard to the black color and polled condition were obtained at the Maine station (112) in crosses of the principal dairy breeds—Holstein, Guernsey, Jersey, and Ayrshire—with Angus cattle. White markings in the inguinal region appeared dominant, while other white markings were in general suppressed by the solid color. The pigmented muzzle and tongue were dominant to the lack of pigment. The black of Holsteins acted as a simple dominant to the red of Guernseys in studies at the Illinois station (28). Crossbred Galloway-Holstein cattle produced at the Alaska station (1) were described as polled black, with more white on the underline than Galloways and resembling Holsteins in hair characters and conformation.

The behavior of colors and horns in crosses of Shorthorns and Galloways has been studied at the Iowa station (50). The black and red pigment form an independent pair of allelomorphic characters. White animals appeared to be due to restricted pigment lacking the dominant extension factor and thus were genetically either blacks or reds. Roans were equally well explained as due to a dominant factor for roan or as the heterozygote for the extension factor. Whites with black ears have appeared in these experiments, but the reverse has not been observed. The horned and polled

[8] Numbers in parentheses refer to references, p. 75.

conditions were shown to be allelomorphic and without evidence of sex linkage. Studies at the Kentucky station (105) indicated that the yellow nose of the Jersey acted as a simple recessive to gray nose. The inheritance of defects in the teeth (348), congenital cataract (38), albinism (30), and a hereditary enlarging of the ears (328) have been described by the Wisconsin, Illinois, and Texas stations.

In a rather extensive study by the Kentucky station (100) of color inheritance in horses, based on studbook records, chestnut appeared to be recessive to all other colors, black was shown to be a simple dominant to chestnut, while bay was black with a dominant restriction factor and gray was due to a factor dominant over all other colors. A factor for roan may also be present which in the dominant condition produces various shades according to the other colors present.

Colors are obviously less conspicuous in their inheritance in sheep than in horses and cattle, but an abnormality in the form of an earless condition acted as a simple Mendelian dominant at the New Hampshire station (285). Sheep heterozygous for this condition had short ears (286).

Color inheritance in swine was investigated at the Kansas station (71, 96) by crossing wild boars, Tamworths, Berkshires, and Duroc-Jerseys. It was found that the Berkshires carried a single dominant factor which caused black, in the absence of which two dominant factors carried by Durocs acted, the presence of either one causing sandiness or both together causing red. A dilution factor linked with black may inhibit the action of one of the factors for sandiness. A single factor for immature striping and a hypostatic factor for black spotting were carried by the wild boars and by Tamworths.

In studies at the Iowa station (52), the Hampshire black was dominant to Duroc-Jersey red and differed from Berkshire and Poland-China black, since the offspring of crosses of the latter two breeds were predominantly red with black spots. Furthermore, Berkshire and Poland-China black was recessive to the white of Chester-Whites and Yorkshires, while crossbred Hampshire × Chester-Whites were in general blue roans having a white belt. In crosses of mulefoot boars with Duroc-Jerseys at the Illinois station (32), the black color and syndactylous condition were dominant. The operation of intensifying factors was suggested by the variability in the red of the F_2 offspring. The unpublished results of experiments in which a Cheshire boar was crossed with Essex sows at the New York Cornell station showed that the F_1 pigs were white with a few black hairs. The F_2s produced were classified as 34 white, 11 black, and 4 spotted.

Color inheritance in poultry has been studied at several of the stations. Factors were designated for determining various colors in fowls as a result of experiments at the Connecticut station (9). E^m was designated as responsible for extending black to all parts of the plumage, while the recessive e^m restricted the black to the wings and tail (buff and Columbian). The sex-linked factor S determined silver as in the Columbian and duckwing patterns, while s was not silvered. The action of E^m was confirmed at the Kansas station (69) and was shown to be distinct from E, which was involved in the production of black in the presence of a factor P. Black was restricted by R to blue in Andalusians (65). A factor I^p in Leghorns inhibited the action of P to produce white. The massing of black in contour feathers may be due to a fourth factor. At the Missouri station (274) spangling was found to be due to a sex-linked factor and hen feathering in Sebright bantams to be a dominant non-sex-linked factor.

An extensive series of investigations on the inheritance of color in pigeons has been conducted at the Rhode Island and Wisconsin stations (319, 373, 374, 375). These include detailed genetic analyses of various colors and patterns, microscopical and chemical studies of feather pigments, linkage relations of certain sex-linked characters, and a detailed study of the factors involved in the production of checks, bars, and other modifications of black.

Laboratory animals have also been used to some extent for studies of color inheritance by the stations, but not to the same extent as at other institutions. At the Wisconsin station (366) a synthetic pink-eyed self-white guinea pig having all the characteristics of an albino but genetically colored was produced. This station likewise proved the factors for black, tortoise, and yellow in this animal to form a multiple allelomor-

phic series. Congenital palsy in the guinea pig was found to be inherited as a simple Mendelian recessive (357). A series of papers also published from this station (362, 363, 364, 365) dealt with tricolor inheritance in the guinea pig, basset hound, and tortoise-shell cat.

Linkage relationships in rats and mice were studied at the Wisconsin and Illinois stations. In the former case (367), the linkage of redeye, albinism, and pinkeye in the rat as reported by Castle was confirmed, but a lack of linkage was found between the red-eyed allelomorphs and the self-Irish-hooded set of allelomorphs, between redeye and agouti, and between agouti and self, thus indicating that the five known sets of allelomorphs concerned with coat color in rats belong to three linkage groups. At the latter station, no linkage in mice was observed between the agouti, dark-eyed, and black body factors.

One of the most extensive series of allelomorphs known has been reported in the genus Paratettix from the Kansas station (74, 75, 76). In this grasshopper 14 different color patterns are considered to form a series of multiple allelomorphs.

SEX DETERMINATION AND SECONDARY SEX CHARACTERS

The hypothesis that the male is heterozygous and the female homozygous for the sex chromosomes has not only been well established genetically by means of sex-linked characters, but cytological studies have definitely shown such a condition to exist in the domestic animals (20, 21, 22, 23, 24, 25, 26). In poultry the evidence points toward a slightly different mechanism, in which the female is heterozygous and the male homozygous for the sex-determining chromosome, although the results of cytological studies have hardly been numerous enough for a complete confirmation of this hypothesis.

The Wisconsin station, using rabbits as the experimental animals, attempted to separate the male- and female-producing sperms by centrifuging the semen, but the results were negative (341). Using the same animal, the effect of excessive sexual activity on the sex ratio and other characters was investigated at the Iowa station (53, 54). Repeated services by bucks of upward of 20 times in three hours resulted in a decrease, at the fifteenth and particularly the twentieth service, in the amount of semen recovered, the number of sperms produced, the proportion of sperms showing normal movement, the amount of movement, and the percentage of pregnancies. No decrease in the litter size was observed except at the twentieth service. The offspring were in no way inferior in size or vigor, although there seemed to be a low proportion of males with the heavy service. It was concluded that excessive sexual activity exerted a selective action on the sperm cells, eliminating the majority of the male-producing spermatozoa, while the larger female-producing sperms showed lower mortality and greater endurance or for some other cause were superior to the smaller male-producing cells.

The Kansas station (64) found in guinea pigs that the sex ratio was not influenced by the litter size, season of year, still-born animals, or those dying before 20 days of age, but the age of the dam seemed to have an influence on the sex ratio, as females 15 months old gave ratios in their offspring of 145 males to 87 females, whereas females 8 months of age produced 192 males to 224 females.

The practical application of sex-linked characters for the determination of the sex of crossbred chicks at hatching was demonstrated at the Connecticut station (15).

The Massachusetts station has conducted a number of investigations with fowls and ducks dealing with the physiological factors affecting the development and modification of the secondary sex characters (238, 241, 243, 244, 245, 246, 248, 250, 252, 253, 256, 257, 260). The effect of castration, ovariotomy, seasonal activity, and histology of the testicles was observed. The Maine station has published a series of 11 papers on sex and the factors affecting secondary sex characters in poultry, cattle, and mice (135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145), and is still conducting other studies. In the investigations with poultry the ovaries and testicles of birds were carefully examined microscopically for determining the influence of corpora lutea, lutein tissue, interstitial tissue, and other components of the gonads on the determination of secondary sex characters. From the results of these and other studies, it was concluded that pathological changes in the gonads tend to cause a change of the secondary sex characters toward those of the opposite sex at the next molting.

The cause and exact nature of free-martins have long been matters of much speculation among cattle breeders and geneticists alike. In a study at the Maine station of the frequency of occurrence of identical twins in cattle (130), it was found that they were very rare. This led to the conclusion that the theory of the free-martin being an undifferentiated male formed by the division of a single male-producing egg is doubtful.

The chromosome control of sex has been generally accepted ever since its discovery by C. E. McClung. In recent years the operation of other factors in sex determination has been indicated so that what have been called intersexual individuals were produced having the genetic constitution of one sex but modified toward the other sex by the operation of other factors. One of the most striking of such cases was described by F. A. E. Crew, in which a hen which had laid eggs developed the secondary sex characters of a cock and finally mated with hens and produced fertile eggs. C. B. Bridges has shown cases of intersexuality in the pomace fly to be due to abnormal relations between the numbers of sets of autosomes and sex chromosomes, while R. Goldschmidt in Germany has explained the intersexual individuals appearing in gypsy-moth crosses as due to variations in the strength of certain strains for maleness and femaleness.

INHERITANCE OF QUANTITATIVE CHARACTERS

Most of the characters in animals which are closely associated with their economic value are not so easily followed in their mode of inheritance as are color and sex. Some of the reasons for this are obvious. Milk and egg production and fertility may be taken as examples. A large number of environmental as well as hereditary factors are working in a closely interrelated manner and exerting a stimulating or depressing influence in determining such characteristics, i. e., food, season, temperature, etc. When the effects of environment are eliminated as far as possible, there is still very good evidence to show that a large number of genetic factors are responsible for milk production, which, because of their closely related interactions, it has been impossible to separate.

Inheritance of milk production.—The action of multiple factors in determining fat percentage was found to occur in a study at the Illinois station of the factors affecting butterfat percentage and milk yield carried out by crossing Guernseys and Holsteins (39). From an analysis of the data accumulated in this experiment in which 47 F_1 and 19 F_2 individuals were produced, it was calculated that 14 genetic factors were involved in the determination of fat percentage. The results of studies of the inheritance of milk and fat production at this station (40), based on records of cow-testing associations and the advanced registry records of the various dairy breeds, led to the formulation of the hypothesis that the energy of the milk produced was the limiting factor in milk production. The conclusion followed that the possibility of combining high milk and fat production in the same individual was highly improbable.

In crosses of Angus cattle with the principal dairy breeds (113, 114) at the Maine station, high milk production proved dominant to low milk production, but high fat percentage was recessive. Angus cattle have also been crossed with Jerseys and Holsteins at the Wisconsin station in a study of the inheritance of milk and meat production (350) with similar results.

The advanced registry records of the dairy breeds furnished many data which formed the basis for a large number of statistical studies at the Maine station on the factors affecting milk and fat production and their inheritance. A part of these results were published as a series of 14 papers on milk secretion (174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187). Several of them dealing with the influence of different ancestors and relatives on milk production and the relation between sisters, cousins, etc., were published in a book (131) dealing with milk secretion in Holstein-Friesian cattle, while many others appeared separately. The results of such statistical work are valuable in furnishing some idea of the variability to be expected in milk production and fat percentages within breeds, and they are particularly valuable from the standpoint of the correlations found between the production of relatives and ancestors. The fallacy of placing weight on distant ancestors because of their outstanding achievements in the way of production in estimating an animal's ability was substantiated. The sire and dam were shown to be equally responsible for the milk yields and fat percentages of their offspring, not only through the correlation coeffi-

cients of parent and offspring but by the approximate equality of the coefficients obtained in correlations between the paternal and maternal granddams and their granddaughters.

The effect of the age of the parent on the offspring's production was investigated by the use of herdbook records at the New York Cornell station (303) with negative results. Pregnancy was found to diminish production in studies at the Kentucky (107) and Missouri (271) stations.

Fertility.—Although milk and fat production are quantitatively determined by an undoubtedly large number of factors, these characters, nevertheless, have an advantage over fertility and body conformation when a genetic analysis is to be made. Definite and complete records are available for the production of individual dairy cattle for periods of various lengths. This is not so with fecundity, and no general records are kept of conformation. The records of registered purebred offspring of individual breeds are kept, but so many of those produced are never registered that studies on the number of offspring based on such records would be of no value.

Most of the fertility work has been done with poultry, in which case egg production is very close to if not the criterion of fertility and this is also the product for which poultry is mainly kept. Flock records and the results of egg-laying contests have been used as raw data for studying seasonal variations in production and the factors responsible for the inheritance of egg production at various of the stations, including Maine (201, 205, 226, 227, 228, 229, 231), Massachusetts (262), New Jersey (293, 294, 295, 296, 297, 298), and Utah (336, 337). Undoubtedly the most definite results from a study of a problem of this sort were obtained at the Maine station (171), in which two factors (one sex-linked) were found responsible for winter egg production. In the double homozygous recessive condition, no winter eggs were produced. When either factor was dominant, either homozygous or heterozygous, less than 30 eggs were produced, but with the presence of the dominant form of both factors over 30 eggs were produced in the winter.

This case is particularly significant in that it points out in a definite way what has been expected to exist in a very complicated manner in the inheritance of quantitative characters. It is unfortunate, however, that these factors do not apply generally to poultry, as a study of the records at the Massachusetts station (251, 255) did not confirm the operation of the sex-linked factor, but a second nonsex-linked factor was indicated. The use of rate of production rather than total production for a period was suggested as a better basis for future work, since the winter laying period of pullets depends on the date of hatching. In studies at this station two factors were indicated as responsible for broodiness (261) and another factor for rate of production (251).

Statistical studies of the data accumulated in the New Jersey egg-laying contests (294, 295) did not indicate that different factors are operative in controlling winter egg production from the factors responsible for production during the rest of the year. In studies at the Rhode Island (321) and New York Cornell (304) stations. the inheritance of characters concerned with the eggs produced, such as color, shape, size, etc., was indicated, but an analysis of the factors involved was not made.

The length of the eggs laid by *Drosophila melanogaster* was found at the Kansas station (80) to be inherited. Several factors were responsible, the major one being sex-linked, while another important one was located in the third chromosome.

The few studies which have been made of fertility in farm animals have been mostly very elementary in nature, and the data obtained have not been sufficiently complete for a detailed genetic analysis.

Conformation and body characters.—The inheritance of differences in type has been studied in cattle, sheep, and swine. In the crosses of the dairy breeds with Angus cattle at the Maine station (112, 113, 114), the type of head and heavy deep-fleshed fore quarters of the Angus were dominant, while body and hind quarters appeared mainly intermediate but showed some resemblance to those of the dairy parents. In crosses of Jersey and Angus cattle at the Wisconsin station (353), no genetic analysis has yet been attempted, though the conformation of the crossbreds tended to be intermediate. The Texas station (327) is studying the inheritance of characters in crosses of Brahman cattle with grade Herefords. The crossbred calves were found to grow more rapidly than purebreds.

An extensive study of the inheritance of size and conformation in

crosses between mutton and fine-wool sheep has been made at the New Hampshire station (292). This experiment consisted mainly in measuring the F_2s and F_3s of Southdown × Rambouillet crosses. Such individuals were smaller than F_1s and their conformation was better than that of Rambouillets but not so good as Southdowns. The wool approached Rambouillet quality in fineness, crimp, and length but had less grease. The growth rate of the animals to 4 or 5 months depended on the dam's milk yield. The general characteristics were usually intermediate in the F_1 with increased variability being evident in the F_2s. These results indicated segregation of the factors concerned in determining size, but there was no evidence of dominance. In making a study of the internal characters, animals of each generation were slaughtered and transections of the carcasses made. The hybrids showed a length of rib similar to the Southdowns but resembled Rambouillets in the width of the thoracic cavity at the base and in the length of the spinous processes, which was closely correlated with the thickness of flesh. Oxford and Rambouillet crosses are being used to study the inheritance of fecundity and milk production.

Studies on the inheritance of wool characters and conformation are being conducted at the California (5), Wyoming (377, 378), and Texas (332), stations, although the results are as yet only preliminary.

Work at the Kansas station (71, 96) has tended to throw some light on the inheritance of breed characteristics in swine. In the crosses the erect ears of the Berkshires were dominant by probably three factors over the lopped ears of Duroc-Jerseys. The face of the wild hog was dominant over the other types of faces, while the shape of the Tamworth's face was dominant to the dished Berkshire face, and the Berkshire was largely but not completely dominant to the Duroc-Jersey type of face. The forehead shape of the Berkshire seemed to be more dominant in crosses than the dish or the length of the face. The number of mammæ was found to be inherited in a general way. There was no greater tendency to variation in the rudimentary nipples of males than in the nipples of females. As the number of mammæ increased there was an increase in the percentage of asymmetry in the pattern, and sows having a larger number of mammæ were found to produce more offspring than sows with the smaller numbers. The paired rudimentaries to the rear of the inguinal pair were observed to be inherited as a simple sex-linked Mendelian character.

The Kansas station (62) is studying the inheritance of size in rats by endeavoring to select pure lines among the descendants of a very large male mated with an ordinary sized female. A male larger than his sire was produced in the F_1 generation.

Summary.—Investigations of the inheritance of quantitative characters have hardly progressed far enough for more than the formulation of the hypothesis that such characteristics are controlled by multiple factors, as H. Nilsson-Ehle found for color in wheat. Many factors, some of which inhibit the action of others, and variations of the relative influence on the character in question further complicate the situation.

The stations have made an excellent beginning in work on the inheritance of milk production which should yield results of much economic importance. The Illinois station has the Bowlker herd in which breeds naturally producing high and low flat percentages in the milk have been crossed, while the Wisconsin and Maine stations have several generations resulting from crosses of the beef and dairy breeds of cattle. A continuation of such projects may be expected to yield many important results in the next few years.

METHODS OF BREEDING

Much material has been published on the advantages and disadvantages of various methods of breeding livestock. A great many popular papers have been very contradictory in their recommendations, as have also the results of some of the experiments conducted, especially on inbreeding. The Maine station published several papers (188, 189, 190, 191, 192, 193, 194, 195) under this title which were based on the available scientific knowledge, and coefficients for calculating the amount of inbreeding were suggested, but even this work has been strongly criticized in recent years.

The experimental work in inbreeding conducted at the experiment stations hardly compares either in extent or thoroughness with the investigations of H. D. King with rats and S. Wright with guinea pigs, but the station work, nevertheless, has

tended to throw some light on the effects of inbreeding with other classes of animals and pointed out the difficulty of predicting what results are to be expected, since the success or failure of inbreeding will depend on the constitution, vigor, and other characteristics of the original stock. In studies of inbreeding with hogs at the Delaware station (17), it was found that inbreeding tended to decrease the certainty of pregnancy, increase mortality, and decrease litter size, although the individual weights were greater. The results of several years continued inbreeding of dairy cattle at the Ohio station have shown no decrease in fertility, but the milk production and size have decreased.

Two inbreeding experiments with poultry have been conducted at the Wisconsin station (355). In one of these, inbreeding by brother and sister matings of Rhode Island Reds, in which selection was made only for desirable color, resulted in decreased viability and hatchability of the eggs from 1912 to 1916, but by starting with new stocks for the second experiment and making selections for hatchability and vigor no deteriorations resulted in the flock bred by similar methods from 1917 to 1921, although later generations have shown some deterioration in vigor. Similar experiments at the Connecticut Storrs station (14) resulted in a rather general and uniform decline, although there was some variability among the different lines. This applied particularly to the percentage of eggs hatched, the number of eggs laid in the first year, the mortality both of chicks to 3 weeks of age and of adult pullets, the growth rate of chicks, rate of sexual maturity, winter egg production, and probably the activity of the vital processes.

At the Massachusetts station (263) inbreeding of Rhode Island Reds tended to decrease winter egg production, and the rate of maturity was retarded. Different lines, however, showed significant differences in production. Inbreeding guinea pigs in experiments at the Kansas station (60) did not produce any decrease in vigor, fecundity, or size.

The composite results of inbreeding experiments, though somewhat contradictory, have tended to bring out the conclusions which have been arrived at in other work on inbreeding in plants and animals, namely, that the main tendency is for a production of homozygosis in the individual lines with consequent reduction in vigor and fertility. It has been suggested that the factors determining these characters are largely dominant, and the production of homozygosis tends to eliminate some of these dominant factors with a resulting decrease of vigor.

PHYSIOLOGY OF REPRODUCTION

That phase of animal genetics dealing with the physiology of reproduction has not received the attention which it has deserved. Work along this line may be expected to yield results which will add important contributions toward the solution of the more intricate problems closely associated with the practical application of the subject. Little is known of the fundamental physiological activities associated with the vital processes. This is particularly true of the processes underlying the determination of secondary sex characters, fecundity, and milk production.

One of the first extensive series of papers on this subject dealt with the physiology of reproduction in the fowl and consisted of 19 papers issued by the Maine station (147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165). These studies dealt with the environmental influence on egg production as well as the influence of internal secretions and the effect of endocrine organs on production. The effect of continued administration of alcohol on the progeny of domestic fowls was also studied at this station (210, 213, 214, 215). As a result of the administration of alcohol, the prenatal mortality was increased, but the postnatal mortality was reduced. Similar results were obtained when the fertile eggs were exposed to alcohol fumes.

Efforts to modify the germ plasm at the Wisconsin station (345, 354) by the use of various toxins were mainly negative in result, sterility being the only evidence of a modification. A waltzing rabbit (360), however, occurred among the descendants of individuals treated with lead and alcohol, which was concluded to be due to an injury to the germ plasm of its ancestors.

The effect of the somatic cells on the germ cells was studied at the New York Cornell station (305) with poultry, much as Castle and Philipps did with guinea pigs. The results obtained at the Cornell station were, however, not in accord with those obtained with guinea pigs. The trans-

ference of ovaries from white birds into black hens resulted in the production of spotted offspring when mated with white roosters.

The position of fetuses in the uterus was studied at the Kansas station with guinea pigs (64) and the results indicated that crowding affected the weight of the placenta which in turn reduced the size of the fetuses.

In investigations at the Kentucky station (101), the semen of stallions, bulls, roosters, and man was studied with regard to the composition, length of life, acidity, and other properties. The primary purpose of this investigation was to throw light on the factors affecting sterility in animal breeding, and further to see how long semen could be kept for artificial insemination. Normal horse semen was found to vary in pH value from 6.94 to 7.51, with an average of 7.31, while inactive semen varied from 7.49 to 7.76. It was found that the spermatozoa of vigorous horse semen kept in the laboratory at 22° C. began to decrease in movement in 2 hours, followed by complete loss of movement in 6 hours. Other temperatures below and above this were less satisfactory. The addition of solutions of 0.045 per cent hydrochloric acid, sulphuric acid, nitric acid, acetic acid, or carbolic acid, 0.0067 per cent potassium permanganate, or 0.25 per cent ethyl alcohol, immediately stopped all activity of the spermatozoa of the horse. From examination of mares and hens killed at intervals after breeding, it was concluded that the secretions of the genital tract tended to prolong the life of the spermatozoa as active sperms were found in all hens from 6 to 8 hours after breeding and in one mare 7.25 hours after insemination.

CONCLUSION

The work of the experiment stations in animal genetics, supplementing that of other institutions, has dealt with various phases of the subject and with different kinds of animals but especially the larger animals. The general status of the work points toward the need of much more data on the inheritance of the characters of economic importance. It may not be possible to accumulate sufficient data at one institution for a proper analysis of such characters, especially in the larger animals. Herein may lie an opportunity for cooperative experiments in which several institutions have a part. The fundamental physiological factors underlying reproduction have likewise not received the attention which they deserve, and progress is at a standstill in certain lines of work until more is known of the physiological factors related to reproduction and development.

REFERENCES

Alaska Stations.

(1) Pratt, H. E. [Experimental cattle crosses in Alaska.] Alaska Stas.. Rpt. 1918, pp. 89, 90.

California Station.

(2) Clausen, R. E. Inheritance in *Drosophila hydei*.—I, White and vermilion eye-colors. Amer. Nat., 57 (1923), No. 648, pp. 52–58.

(3) ——— and Collins, J. L. The inheritance of ski wings in *Drosophila melanogaster*. Genetics, 7 (1922), No. 4, pp. 385–426.

(4) Wilson, J. F. Sheep breeding. Calif. Sta. Rpt. 1921, p. 133.

(5) ——— Studies in sheep breeding. Calif. Sta. Rpt. 1922, pp. 59, 60.

Connecticut Storrs Station.

(6) Dunn, L. C. Types of white spotting in mice. Amer. Nat., 54 (1920), No. 635, pp. 465–495.

(7) ——— Linkage in mice and rats. Genetics, 5 (1920), No. 3, pp. 325–343.

(8) ——— Independent genes in mice. Genetics, 5 (1920), No. 3, pp. 344–361.

(9) ——— Inheritance of plumage color in crosses of buff and Columbian fowls. Amer. Nat., 56 (1922), No. 644, pp. 242–255.

(10) ——— A gene for the extension of black pigment in domestic fowls. Amer. Nat., 56 (1922), No. 646, pp. 464–466.

(11) ——— The relationship between the weight and the hatching quality of eggs. Conn. Storrs Sta. Bul. 109 (1922), pp. 89–114.

(12) A lethal gene in fowls. Amer. Nat., 57 (1923), No. 651, pp. 345–349.

(13) ——— Color inheritance in fowls. Jour. Heredity, 14 (1923), No. 1, pp. 23–32.

(14) ———. Experiments on close inbreeding in fowls.—A preliminary report. Conn. Storrs Sta. Bul. 111 (1923), pp. 139–172.

(15) ——— A method for distinguishing the sex of young chicks. Conn. Storrs Sta. Bul. 113 (1923), pp. 245–280.

(16) ———, Webb, H. F., and Schneider, M. The inheritance of degrees of spotting in Holstein cattle. Jour. Heredity, 14 (1923), No. 5, pp. 229–240.

Delaware Station.

(17) Hays, F. A. Inbreeding animals. Del. Sta. Bul. 123 (1919), p. 49.

(18) Hayward, H. [Inbreeding experiments with pigs.] Del. Sta. Bul. 119 (Rpt. 1917), pp. 17, 18.

Guam Station.

(19) EDWARDS, C. W. Rhode Island Reds crossed with native white hens. Guam Sta. Rpt. 1924, pp. 6, 7.

Idaho Station.

(20) WODSEDALEK, J. E. Spermatogenesis of the pig with special reference to the accessory chromosomes. Biol. Bul. Mar. Biol. Lab. Woods Hole, 25 (1913), No. 1, pp. 8–44.

(21) ——— Spermatogenesis of the horse with special reference to the accessory chromosome and the chromatoid body. Biol. Bul. Mar. Biol. Lab. Woods Hole, 27 (1914), No. 6, pp. 295–324.

(22) ——— Causes of sterility in the mule. Biol. Bul. Mar. Biol. Lab. Woods Hole, 30 (1916), No. 1, pp. 1–56.

(23) ——— Studies on the cells of cattle with special reference to spermatogenesis, oögonia, and sex-determination. Biol. Bul. Mar. Biol. Lab. Woods Hole, 38 (1920), No 5, pp. 290–316.

(24) ——— Studies on the cells of sheep with special reference to spermatogenesis, oögenesis, and sex-determination. Abs. in Anat. Rec., 23 (1922), No. 1, p. 103.

(25) ——— [Inheritance in goats.] Idaho Sta. Circ. 30 (1923), p. 11.

(26) ——— and Smith, R. H. Cytological studies of the reproductive cells of cattle. Idaho Sta. Rpt. 1918, p. 34.

Illinois Station.

(27) ANON. [Inheritance in dairy cattle.] Ill. Sta. Rpt. 1923, p. 20.

(28) CAMPBELL, M. H. Inheritance of black and red coat colors in cattle. Genetics, 9 (1924), No. 5, pp. 419–441.

(29) DETLEFSEN, J. A. Fluctuations of sampling in a Mendelian population. Genetics, 3 (1918), No. 6, pp. 599–607.

(30) ——— A herd of albino cattle. Jour. Heredity, 11 (1920), No. 8, pp. 378, 379.

(31) ——— A new mutation in the house mouse. Amer. Nat., 55 (1921), No. 640, pp. 469–473.

(32) ——— and CARMICHAEL, W. J. Inheritance of syndactylism, black, and dilution in swine. Jour. Agr. Research [U. S.], 20 (1921), No. 8, pp. 595–604.

(33) ——— and CLEMENTE, L. S. Genetic variation in linkage values. Natl. Acad. Sci. Proc., 9 (1923), No. 5, pp. 149–156.

(34) ——— and HOLBROOK, F. M. Skunk breeding, with notes on mutations and their genetic behavior. Jour. Heredity, 12 (1921), No. 6, pp. 242–254.

(35) ——— and ROBERTS, E. On a back cross in mice involving three allelomorphic pairs of characters. Genetics, 3 (1918), No. 6, pp. 573–598.

(36) ——— ——— Linkage of genetic factors in mice. Abs. in Anat. Rec., 17 (1920), No. 5, p. 338.

Illinois Station—Continued.

(37) DETLEFSEN, J. A., and ROBERTS, E. Studies on crossing over.—I, The effect of selection on crossover values. Jour. Expt. Zool., 32 (1921), No. 2, pp. 333–354.

(38) ——— and YAPP, W. W. The inheritance of congenital cataract in cattle. Amer. Nat., 54 (1920), No. 632, pp. 277–280.

(39) GAINES, W. L. The inheritance of fat content of milk in dairy cattle. Amer. Soc. Anim. Prod. Proc. 1922, pp. 29–32.

(40) ——— and DAVIDSON, F. A. Relation between percentage, fat content, and yield of milk.—Correction of milk yield for fat content. Ill. Sta. Bul. 245 (1923), pp. 577–621.

(41) RIETZ, H. L., and ROBERTS, E. Degree of resemblance of parents and offspring with respect to birth as twins for registered Shropshire sheep. Jour. Agr. Research [U. S.], 4 (1915), No. 6, pp. 479–510.

(42) ROBERTS, E. Fluctuations in a recessive Mendelian character and selection. Jour. Expt. Zool., 27 (1918), No. 2, pp. 157–192.

(43) ——— Fertility in Shropshire sheep. Jour. Agr. Research [U. S.], 22 (1921), No. 4, pp. 231–234.

(44) ——— Polydactylism in cattle. Jour. Heredity, 12 (1921), No. 2, pp. 84–86.

(45) WRIEDT, C. Correlation between the size of cannon bone in the offspring and the age of the parents. Jour. Agr. Research [U. S.], 7 (1916), No. 8, pp. 361–371.

Indiana Station.

(46) PHILIPS, A. G. Preferential mating of fowls. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 5 (1919), No. 4, pp. 28, 30–32.

(47) SMITH, W. W. Color inheritance in swine. Amer. Breeders Mag., 4 (1913), No. 2, pp. 113–123.

Iowa Station.

(48) KILDEE, H. H., and MCCANDLISH, A. C. Influence of environment and breeding in increasing dairy production. Iowa Sta. Bul. 165 (1916), pp. 381–402.

(49) MCCANDLISH, A. C., GILLETTE, L. S., and KILDEE, H. H. Influence of environment and breeding in increasing dairy production, II. Iowa Sta. Bul. 188 (1919), pp. 61–88.

(50) LLOYD-JONES, O. Mules that breed. Jour. Heredity, 7 (1916), No. 11, pp. 494–502.

(51) ——— and EVVARD, J. Inheritance of color and horns in blue-gray cattle. Iowa Sta. Research Bul. 30 (1916), pp. 67a–106a.

(52) ——— ——— Studies on color in swine.—I, The hereditary relationship of the black of the Hampshire and the red of the Duroc-Jersey. Iowa Sta. Research Bul. 53 (1919), pp. 203–208.

Iowa Station—Continued.

(53) LLOYD-JONES, O., and HAYS, F. A. The influence of excessive sexual activity of male rabbits.—I, On the properties of the seminal discharge. Jour. Expt. Zool., 25 (1918), No. 2, pp. 463–497.

(54) HAYS, F. A. The influence of excessive sexual activity of male rabbits.—II, On the nature of their offspring. Jour. Expt. Zool., 25 (1918), No. 2, pp. 571–613.

(55) MCCANDLISH, A. C. Environment and breeding as factors influencing milk production. Jour. Heredity, 11 (1920), No. 5, pp. 204–214.

(56) WENTWORTH, E. N. Concerning "blue-gray" cattle. Amer. Breeder, 5 (1912), No. 2, pp. 9, 10.

Kansas Station.

(57) ANON. Inheritance investigation in swine. Kans. Sta. Rpt. 1915–1916, p. 19.

(58) ——— [Inheritance of color in Andalusian fowl.] Kans. Sta. Rpt. 1918, p. 45.

(59) ——— Inheritance in Orthoptera. Kans. Sta. Rpt. 1920. p. 39.

(60) ——— Inheritance in guinea pigs. Kans. Sta. Rpt. 1920, pp. 39, 40.

(61) ANON. [The inheritance of characters in poultry.] Kans. Sta. Bien. Rpt. 1923–24, pp. 106, 107.

(62) ——— Studies in animal reproduction and inheritance. Kans. Sta. Bien. Rpt. 1923–24, pp. 116–118.

(63) ——— Studies of inheritance in the grouse locusts (Tettigidae). Kans. Sta. Bien. Rpt. 1923–24, pp. 118, 119.

(64) IBSEN, H. L. Some genetic experiments with guinea-pigs and rats. Amer. Soc. Anim. Prod. Proc. 1922, pp. 99–101.

(65) LIPPINCOTT, W. A. The case of the blue Andalusian. Amer. Nat., 52 (1918), No. 614, pp. 95–115.

(66) ——— The breed in poultry and pure breeding. Jour. Heredity, 10 (1919), No. 2, pp. 71–79.

(67) ——— A hen which changed color. Jour. Heredity, 11 (1920), No. 8, pp. 342–348.

(68) ——— Further data on the inheritance of blue in poultry. Amer. Nat., 55 (1921), No. 639, pp. 289–327.

(69) ——— Genes for the extension of black pigment in the chicken. Amer. Nat., 57 (1923), No. 650, pp. 284–287.

(70) ——— The hereditary relation of dominant white and blue in chickens. Poultry Sci., 2 (1923), No. 5, pp. 141–145.

(71) LUSH, J. L. Inheritance in swine. Jour. Heredity, 12 (1921), No. 2, pp. 57–71.

(72) NABOURS, R. K. Evidence of alternative inheritance in the F_2 generation from crosses of *Bos indicus* on *Bos taurus*. Amer. Nat., 46 (1912), No. 547, pp. 428–436.

Kansas Station—Continued.

(73) NABOURS, R. K. Possibilities for a new breed of cattle for the South. Amer. Breeders Mag., 4 (1913), No. 1, pp. 38–52.

(74) ——— Studies of inheritance and evolution in Orthoptera, I. Jour. Genetics, 3 (1914), No. 3, pp. 141–170.

(75) ——— Studies of inheritance and evolution in Orthoptera, II, III. Jour. Genetics, 7 (1917), No. 1, pp. 1–54; abs. in Anat. Rec., 11 (1917), No. 6, pp. 500, 501.

(76) BELLAMY, A. W. Studies of inheritance and evolution in Orthoptera.—IV, Multiple allelomorphism and inheritance of color patterns in Tettigidea. Jour. Genetics, 7 (1917), No. 1, pp. 55–70.

(77) NABOURS, R. K. Parthogenesis and crossing-over in the grouse locust Apotettix. Amer. Nat., 53 (1919), No. 625, pp. 131–142.

(78) ——— A new dominant color pattern and combinations that breed true in the grouse locusts. Genetica [The Hague], 5 (1923), No. 5–6, pp. 477–480.

(79) PAYNE, F. *Drosophila ampelophila* Loew bred in the dark for sixty-nine generations. Biol. Bul. Mar. Biol. Lab. Woods Hole, 21 (1911), No. 5, pp. 297–301.

(80) WARREN, D. C. Inheritance of egg size in *Drosophila melanogaster*. Genetics, 9 (1924), No. 1, pp. 41–69.

(80) WENTWORTH, E. N. Inheritance of mammae in swine. Amer. Breeders Assoc. Proc., 8 (1912), pp. 545–549.

(82) ——— Segregation in cattle. Amer. Breeders Assoc. Proc., 8 (1912), pp. 572–580.

(83) ——— Color in Shorthorn cattle. Amer. Breeders Mag., 4 (1913), No. 4, pp. 202–208.

(84) ——— Inheritance of mammae in Duroc Jersey swine. Amer. Nat., 47 (1913), No. 557, pp. 257–278.

(85) ——— The segregation of fecundity factors in Drosophila. Jour. Genetics, 3 (1913), No. 2, pp. 113–120.

(86) ——— Sex-linked factors in the inheritance of rudimentary mammae in swine. Iowa Acad. Sci. Proc., 21 (1914), pp. 265–268.

(87) ——— Color inheritance in the horse. Ztschr. Induktive Abstam. u. Vererbungslehre, 11 (1914), No. 1–2, pp. 10–17.

(88) ——— Prepotency. Jour. Heredity, 6 (1915), No. 1, pp. 17–20.

(89) ——— Large-type swine and fertility. Breeder's Gaz., 69 (1916), No. 13, pp. 722, 723.

(90) ——— A sex-limited color in Ayrshire cattle. Jour. Agr. Research [U. S.], 6 (1916), No. 4, pp. 141–147.

(91) ——— Inheritance of fertility in sheep. Kans. Acad. Sci. Trans., 28 (1916–17), pp. 243, 244.

Kansas Station—Continued.

(92) Wentworth, E. N. Inheritance of fertility in Southdown sheep. Amer. Nat., 51 (1917), No. 611, pp. 662–682.

(93) ——— The influence of the male on litter sizes. Iowa Acad. Sci. Proc., 24 (1917), pp. 305–308.

(94) ——— Selecting cattle for hornlessness. Breeder's Gaz., 76 (1919), No. 17, pp. 849, 850.

(95) Wentworth, E. N., and Aubel, C. E. Inheritance of fertility in swine. Jour. Agr. Research [U. S.], 5 (1916), No. 25, pp. 1145–1160.

(96) ——— and Lush, J. L. Inheritance in swine. Jour. Agr. Research [U. S.], 23 (1923), No. 7, pp. 557–582.

(97) ——— and Remick, B. L. Some breeding properties of the generalized Mendelian population. Genetics, 1 (1916), No. 6, pp. 608–616.

(98) ——— and Sweet, J. B. Inheritance of fertility in Southdown sheep. Amer. Nat., 51 (1917), No. 611, pp. 662–682.

Kentucky Station.

(99) Anderson, W. S. The inheritance of coat color in horses. Amer. Nat., 47 (1913), No. 562, pp. 615–624.

(100) ——— The inheritance of coat colors in horses. Ky. Sta. Bul. 180 (1914), pp. 121–145.

(101) ——— Vitality of spermatozoa. Ky. Sta. Bul. 239 (1922), p. 36.

(102) ——— Sterility in relation to animal breeding. Ky. Sta. Bul. 244 (1922), pp. 201–234.

(103) ——— The influence of great sires on their breeds. Amer. Soc. Anim. Prod. Proc. 1922, pp. 120–122.

(104) Hooper, J. J. Inheritance of Jersey colors. Jour. Dairy Sci., 2 (1919), No. 4, pp. 290–292.

(105) ——— Studies of dairy cattle.—I, Inheritance of color markings in Jersey cattle. Ky. Sta. Bul. 234 (1921), pp. 95–114.

(106) ——— Studies of dairy cattle.—II, Influence of oestrum or heat on the production of milk and butter fat. Ky. Sta. Bul. 234 (1921), pp. 115–118.

(107) ——— Studies of dairy cattle.—III, Influence of age and pregnancy on the production of milk and butter fat in Jersey cows. Ky. Sta. Bul. 234 (1921), pp. 119–125.

(108) ——— Color of crossbred calves. Jour. Heredity, 12 (1921), No. 10, p. 480.

(109) ——— and Bacon, P. E. Heat period and milk production. Breeder's Gaz., 75 (1919), No. 15, pp. 844, 845.

Maine Station.

(110) Boring, A. M., and Pearl, R. The odd chromosome in the spermatogenesis of the domestic chicken. Jour. Expt. Zool., 16 (1914), No. 1, pp. 53–83.

(111) Curtis, M. R. Factors influencing the size, shape, and physical constitution of the egg of the domestic fowl. Me. Sta. Bul. 228 (1914), pp. 105–136.

(112) Gowen, J. W. Studies in inheritance of certain characters of crosses between dairy and beef breeds of cattle. Jour. Agr. Research [U. S.], 15 (1918), No. 1, p. 58.

(113) ——— Inheritance in crosses of dairy and beef breeds of cattle.—II, On the transmission of milk yield to the first generation. Jour. Heredity, 11 (1920), No. 7, pp. 300–316; abs. in Me. Sta. Bul. 295 (1920), pp. 217–219.

(114) ——— Inheritance in crosses of dairy and beef breeds of cattle.—III, Transmission of butter-fat percentage to the first generation. Jour. Heredity, 11 (1920), No. 8, pp. 365–376; abs. in Me. Sta. Bul. 295 (1920), pp. 219, 220.

(115) ——— Inheritance studies of certain color and horn characteristics in first generation crosses of dairy and beef breeds. Me. Sta. Bul. 272 (1918), pp. 129–148.

(116) ——— Report of progress on animal husbandry investigation in 1917. Me. Sta. Bul. 274 (1918), pp. 205–228.

(117) ——— Variations and mode of secretion of milk solids. Jour. Agr. Research [U. S.], 16 (1919), No. 3, pp. 79–102.

(118) ——— A biometrical study of crossing over.—On the mechanism of crossing over in the third chromosomes of *Drosophila melanogaster*. Genetics, 4 (1919), No. 3, pp. 205–250; abs. in Me. Sta. Bul. 284 (1919), p. 300.

(119) ——— Appliances and methods for pedigree poultry breeding at the Maine Station. Me. Sta. Bul. 280 (1919), pp. 65–88.

(120) ——— Report of progress on animal husbandry investigations in 1919. Me. Sta. Bul. 283 (1919), pp. 249–284.

(121) ——— Conformation and its relation to milk producing capacity in Jersey cattle. Jour. Dairy Sci., 3 (1920), No. 1, pp. 1–32; abs. in Me. Sta. Bul. 284 (1919), pp. 298–300.

(122) ——— Studies on conformation in relation to milk producing capacity in cattle.—II. The personal equation of the cattle. Jour. Dairy Sci., 4 (1921), No. 5, pp. 359–374.

(123) ——— The variation of milk secretion with age in Jersey cattle. Me. Sta. Bul. 286 (1920), pp. 49–60.

Maine Station—Continued.

(124) GOWEN, J. W. The correlation between milk yield of one lactation and that of succeeding lactations. Me. Sta. Bul. 289 (1920), pp. 121–132.
(125) ——— The variation of butter-fat percentage with age in Jersey cattle. Me. Sta. Bul. 290 (1920), pp. 133–144.
(126) ——— The correlation between butter-fat percentage of one lactation and the butter-fat percentage of succeeding lactations in Jersey cattle. Me. Sta. Bul. 291 (1920), pp. 145–156.
(127) ——— The relation of conformation to milk yield in Jersey cattle. Me. Sta. Doc. 538 (1920), pp. 12.
(128) ——— Report of progress on animal husbandry investigations in 1920. Me. Sta. Bul. 299 (1921), pp. 85–120.
(129) ——— The inheritance of milk yield and some of its practical applications. Amer. Soc. Anim. Prod. Proc. 1922, pp. 102–104.
(130) ——— Identical twins in cattle. Biol. Bul. Mar. Biol. Lab. Woods Hole, 42 (1922), No. 1, pp. 1–6.
(131) ——— Milk secretion. Baltimore: 1924, pp. 363.
(132) ——— The intrauterine development of the bovine fetus in relation to milk yield in Guernsey cattle. Jour. Dairy Sci., 7 (1924), No. 4, pp. 311–317.
(133) GOWEN, M. S. and J. W. Complete linkage in *Drosophila melanogaster*. Amer. Nat., 56 (1922), No. 644, pp. 286–288.
(134) LITTLE, C. C., and JONES, E. E. The effect of selection upon a Mendelian ratio. Genetics, 8 (1923), No. 1, pp. 1–26.
(135) PEARL, M. D. and R. [Sex studies.—I], On the relation of race crossing to the sex ratio. Biol. Bul. Mar. Biol. Lab. Woods Hole, 15 (1908), No. 4, pp. 194–205.
(136) PEARL, R. [Sex studies.—II], A case of hypospadias in a ram. Amer. Vet. Rev., 40 (1912), No. 6, pp. 794–796.
(137) BORING, A. M. [Sex studies.—III], The interstitial cells and the supposed internal secretion of the chicken testis. Biol. Bul. Mar. Biol. Lab. Woods Hole, 23 (1912), No. 3, pp. 144–153.
(138) PEARL, R. and BORING, A. M. [Sex studies.—IV], Fat deposition in the testis of the domestic fowl. Science, 36 (1912), No. 937, pp. 833–835.
(139) ——— and PARSHLEY, H. M. [Sex studies.—V], Data on sex determination in cattle. Biol. Bul. Mar. Biol. Lab. Woods Hole, 24 (1913), No. 4, pp. 205–225.
(140) ——— and SALAMAN, R. N. [Sex studies.—VI], The relative time of fertilization of the ovum and the sex ratio amongst Jews. Amer. Anthropol., n. ser., 15 (1913), No. 4, pp. 668–674.

Maine Station—Continued.

(141) PEARL, R., and SURFACE, F. M. Sex studies.—VII, On the assumption of male secondary characters by a cow affected with cystic degeneration of the ovaries. Me. Sta. Bul. 237 (1915), pp. 65–80.
(142) ——— [Sex studies.—VIII], The sex ratio in the domestic fowl. Amer. Phil. Soc. Proc., 56 (1917), No. 5, pp. 416–436; abs. in Me. Sta. Bul. 268 (1917), p. 309.
(143) BORING, A. M., and PEARL R. Sex studies.—IX, Interstitial cells in the reproductive organs of the chicken. Anat. Rec., 13 (1917), No. 5, pp. 253–268; abs. in Me. Sta. Bul. 268 (1917), p. 308.
(144) PEARL, R., and BORING, A. M. Sex studies.—X, The corpus luteum in the ovary of the domestic fowl. Amer. Jour. Anat., 23 (1918), No. 1, pp. 1–36.
(145) BORING, A. M., and PEARL, R. Sex studies.—XI, Hermaphrodite birds. Jour. Expt. Zool., 25 (1918), No. 1, pp. 1–47.
(146) PEARL, M. D. and R. On the relation of race crossing to the sex ratio. Biol. Bul. Mar. Biol. Lab. Woods Hole, 15 (1908), No. 4, pp. 194–205; abs. in Jour. Roy Micros. Soc. [London], 1909, pt. 1, p. 33.
(147) PEARL, R. Studies on the physiology of reproduction in the domestic fowl.—I, Regulation in the morphogenetic activity of the oviduct. Jour. Expt. Zool., 6 (1909), No. 3, pp. 339–359.
(148) ——— and SURFACE, F. M. [Studies on the physiology of reproduction in the domestic fowl.—II], Data on the inheritance of fecundity obtained from the records of egg production of the daughters of "200-egg" hens. Me. Sta. Bul. 166 (1909), pp. 49–84.
(149) ——— and CURTIS, M. R. Studies on the physiology of reproduction in the domestic fowl.—III, A case of incomplete hermaphroditism. Biol. Bul. Mar. Biol. Lab. Woods Hole, 17 (1909), No. 4, pp. 271–286.
(150) ——— and SURFACE, F. M. [Studies on the physiology of reproduction in the domestic fowl.—IV], Data on certain factors influencing the fertility and hatching of eggs. Me. Sta. Bul. 168 (1909), pp. 105–164.
(151) ——— and CURTIS, M. R. Studies on the physiology of reproduction in the domestic fowl.—V, Data regarding the physiology of the oviduct. Jour. Expt. Zool., 12 (1912), No. 1, pp. 99–132.
(152) CURTIS, M. R. Studies on the physiology of reproduction in the domestic fowl.—VI, Double and triple-yolked eggs. Biol. Bul. Mar. Biol. Lab. Woods Hole, 26 (1914), No. 2, pp. 55–83.

Maine Station—Continued.

(153) Pearl, R. Studies on the physiology of reproduction in the domestic fowl.—VII, Data regarding the brooding instinct in its relation to egg production. Jour. Anim. Behavior, 4 (1914), No. 4, pp. 266–288; abs. in Me. Sta. Bul. 234 (1914), pp. 284, 285.

(154) ——— and Curtis, M. R. Studies on the physiology of reproduction in the domestic fowl.—VIII, On some physiological effects of ligation, section, or removal of the oviduct. Jour. Expt. Zool., 17 (1914), No. 3, pp. 395–424; abs. in Me. Sta. Bul. 234 (1914), pp. 285, 286.

(155) ——— and Surface, F. M. Studies on the physiology of reproduction in the domestic fowl.—IX, On the effect of corpus luteum substance upon ovulation in the fowl. Jour. Biol. Chem., 19 (1914.) No. 2, pp. 263–278; abs. in Me. Sta. Bul, 234 (1914), p. 286.

(156) Curtis, M. R., and Pearl, R. Studies on the physiology of reproduction in the domestic fowl.—X, Further data on somatic and genetic sterility. Jour. Expt. Zool., 19 (1915), No. 1, pp. 45–59; abs. in Me. Sta. Bul. 234 (1914), p. 287.

(157) ——— [Studies on the physiology of reproduction in the domestic fowl.—XI,] Relation of simultaneous variation to the production of double-yolked eggs. Jour. Agr. Research [U. S.], 3 (1915), No. 5, pp. 375–386.

(158) ——— Studies on the physiology of reproduction in the domestic fowl.—XII, On an abnormality of the oviduct and its effect upon reproduction. Biol. Bul. Mar. Biol. Lab. Woods Hole, 28 (1915), No. 3, pp. 154–162.

(159) Pearl, R., and Surface, F. M. Studies on the physiology of reproduction in the domestic fowl.—XIII, On the failure of extract of pituitary body (anterior lobe) to activate the resting ovary. Jour. Biol. Chem., 21 (1915), No. 1, pp. 95–101.

(160) ——— Studies on the physiology of reproduction in the domestic fowl.—XIV, The effect of feeding pituitary substance and corpus luteum substance on egg production and growth. Jour. Biol. Chem., 24 (1916), No. 2, pp. 123–135.

(161) ——— and Curtis, M. R. Studies on the physiology of reproduction in the domestic fowl.—XV, Dwarf eggs. Jour. Agr. Research [U. S.], 6 (1916), No. 25, pp. 977–1042.

(162) Curtis, M. R. Studies on the physiology of reproduction in the domestic fowl.—XVI, Double eggs. Biol. Bul. Mar. Biol. Lab. Woods Hole, 31 (1916), No. 3, pp. 181–212.

Maine Station—Continued.

(163) Pearl, R. Studies on the physiology of reproduction in the domestic fowl.—XVII, The influence of age upon reproductive ability, with a description of a new reproductive index. Genetics, 2 (1917), No. 5, pp. 417–432.

(164) ——— and Schoppe, W. F. Studies on the physiology of reproduction in the domestic fowl.—XVIII, Further observations on the anatomical basis of fecundity. Jour. Expt. Zool., 34 (1921), No. 1, pp. 100–118.

(165) ——— and Fairchild, T. E. Studies on the physiology of reproduction in the domestic fowl.—XIX, On the influence of free choice of food materials on winter egg production and body weight. Amer. Jour. Hyg., 1 (1921), No. 3, pp. 253–277.

(166) ——— Breeding for production in dairy cattle in the light of recent advances in the study of inheritance. Agr. of Maine, 1909, pp. 190–200.

(167) ——— Inheritance of hatching quality of eggs in poultry. Amer. Breeders Mag., 1 (1910), No. 2, pp. 129–133.

(168) ——— Inheritance in "blood lines" in breeding animals for performance, with special reference to the "200-egg hen." Amer. Breeders Assoc. [Proc.], 6 (1910), pp. 317–326.

(169) ——— Inheritance of fecundity in the domestic fowl. Amer. Nat., 45 (1911), No. 534, pp. 321–345.

(170) ——— Breeding poultry for egg production. Me. Sta. Bul. 192 (1911), pp. 111–176.

(171) ——— The mode of inheritance of fecundity in the domestic fowl. Jour. Expt. Zool., 13 (1912), No. 2, pp. 153–268; also in Me. Sta. Bul. 205 (1912), pp. 283–394.

(172) ——— A case of triplet calves with some general considerations regarding multiple gestation in normally uniparous animals. Me. Sta. Bul. 204 (1912), pp. 259–282.

(173) ——— The inheritance of fecundity. Pop. Sci. Mo., 81 (1912), No. 4, pp. 364–373.

(174) ——— [Studies in milk secretion].—I, Constants for normal variation in the fat content of mixed milk. Me. Sta. Bul. 221 (1913), pp. 299–305.

(175) ———[Studies in milk secretion].—II, On the law relating milk flow to age in dairy cattle. Soc. Expt. Biol. and Med. Proc., 12 (1914), No. 1, pp. 18, 19.

(176) ——— and Patterson, S. W. [Studies in milk secretion.—III], The change of milk flow with age, as determined from seven day records of Jersey cows. Me. Sta. Bul. 262 (1917), pp. 143–152.

Maine Station—Continued.

(177) GOWEN, J. W. [Studies in milk secretion. — IV], Variations and mode of secretion of milk solids. Jour. Agr. Research [U. S.], 16 (1919), No. 3, pp. 79–102.

(178) ——— [Studies in milk secretion].—V, On the variations and correlations of milk secretion with age. Genetics, 5 (1920), No. 2, pp. 111–188.

(179) ——— Studies in milk secretion.—VI, On the variations and correlations of butter-fat percentage with age in Jersey cattle. Genetics, 5 (1920), No. 3, pp. 249–324; abs. in Me. Sta. Bul. 284 (1919), pp. 291–296.

(180) PEARL, R., GOWEN, J. W., and MINER, J. R. Studies in milk secretion.—VII, Transmitting qualities of Jersey sires for milk yield, butter-fat percentage, and butter-fat. Me. Sta. Bul. 281 (1919), pp. 89–164, 165–204.

(181) GOWEN, J. W. Studies in milk secretion.—VIII, On the influence of age on milk yield and butter-fat percentage, as determined from 365 day records of Holstein-Friesian cattle. Me. Sta. Bul. 293 (1920), pp. 185–196.

(182) ——— and COVELL, M. R. Studies in milk secretion.—IX, On the performance of the progeny of Holstein-Friesian sires. Me. Sta. Bul. 300 (1921), pp. 121–252.

(183) ——— Studies in milk secretion.—X, The relation between the milk yield of one lactation and the milk yield of a subsequent lactation in Guernsey advanced registry cattle. Abs. in Me. Sta. Bul. 304 (1921), p. 349.

(184) ——— Studies in milk secretion.—XI, Relation between the butterfat percentage of one lactation and the butterfat percentage of a subsequent lactation in Guernsey advanced registry cattle. Jour. Dairy Sci., 6 (1923), No. 4, pp. 330–346; abs. in Me. Sta. Bul. 304 (1921), pp. 350, 351.

(185) ——— and COVELL, M. R. Studies in milk secretion.—XII, Transmitting qualities of Holstein-Friesian sires for milk yield, butter-fat percentage, and butter-fat. Me. Sta. Bul. 301 (1921), pp. 253–308.

(186) ——— Studies in milk secretion.—XIII, Relation between the milk yields and butter-fat percentages of the 7 day and 365 day tests of Holstein-Friesian advanced registry cattle. Abs. in Me. Sta. Bul. 304 (1921), pp. 352, 353.

(187) ——— Studies in milk secretion.—XIV, The effect of age on milk yields and butter-fat percentages of Guernsey advanced registry cattle. Me. Sta. Bul. 311 (1923), pp. 9–20.

Maine Station—Continued.

(188) PEARL, R. [Studies on inbreeding.—I], A contribution towards an analysis of the problem of inbreeding. Amer. Nat., 47 (1913), No. 562, pp. 577–614.

(189) ——— and MINER, J. R. [Studies on inbreeding.—II], Tables for calculating coefficients of inbreeding. Me. Sta. Bul. 218 (1913), pp. 189–202.

(190) ——— [Studies on inbreeding.—III], On the results of inbreeding a Mendelian population: A correction and extension of previous conclusions. Amer. Nat., 48 (1914), No. 565, pp. 57–62.

(191) ——— Studies on inbreeding.—IV, On a general formula for the constitution of the n^{th} generation of a Mendelian population in which all matings are of brother × sister. Amer. Nat., 48 (1914), No. 572, pp. 491–494; abs. in Me. Sta. Bul. 234 (1914), p. 288.

(192) ——— Studies on inbreeding.—V, Inbreeding and relationship coefficients. Amer. Nat., 48 (1914), No. 573, pp. 513–523; abs. in Me. Sta. Bul. 234 (1914), p. 288.

(193) ——— Studies on inbreeding.—VI, Some further considerations regarding cousin and related kinds of mating. Amer. Nat., 49 (1915), No. 585, pp. 570–575.

(194) ——— Studies on inbreeding.—VII, Some further considerations regarding the measurement and numerical expression of degrees of kinship. Amer. Nat., 51 (1917), No. 609, pp. 545–559.

(195) ——— Studies on inbreeding.—VIII, A single numerical measure of the total amount of inbreeding. Amer. Nat., 51 (1917), No. 610, pp. 636–639.

(196) ——— On the correlation between the number of mammae of the dam and size of litter in mammals.—I, Interracial correlation. Soc. Expt. Biol. and Med. Proc., 11 (1913), No. 1, pp. 27–30.

(197) ——— On the correlation between the number of mammae of the dam and size of litter in mammals.—II. Intraracial correlation in swine. Soc. Expt. Biol. and Med. Proc., 11 (1913), No. 1, pp. 31, 32.

(198) ——— The measurement of the intensity of inbreeding. Me. Sta. Bul. 215 (1913), pp. 121–138.

(199) ——— Variation in the tongue color of Jersey cattle. Soc. Prom. Agr. Sci. Proc., 34 (1913), pp. 49–57.

(200) ——— The distribution of a Mendelian population in successive generations with continued brother × sister mating. Amer. Nat., 48 (1914), No. 565, pp. 58–62.

Maine Station—Continued.

(201) Pearl, R. The measurement of changes in the rate of fecundity of the individual fowl. Science, 40 (1914), No. 1028, pp. 383, 384; abs. in Me. Sta. Bul. 234 (1914), pp. 283, 284.

(202) ——— Cattle breeding problems and their solution. Agr. of Maine, 1915, pp. 215–242.

(203) ——— Mendelian inheritance of fecundity in the domestic fowl, and average flock production. Amer. Nat., 49 (1915), No. 581, pp. 306–317.

(204) ——— Seventeen years selection of a character showing sex-linked Medelian inheritance. Amer. Nat., 49 (1915) No. 586, pp. 595–608.

(205) ——— Measurement of the winter cycle in the egg production of domestic fowl. Jour. Agr. Research [U. S.], 5 (1915), No. 10, pp. 429–437.

(206) ——— Further data on the measurement of inbreeding. Me. Sta. Bul. 243 (1915), pp. 223–248.

(207) ——— A system of recording types of mating in experimental breeding operations. Science, 42 (1915), No. 1081, pp. 383–386.

(208) ——— Fecundity in the domestic fowl and the selection problem. Amer. Nat., 50 (1916), No. 590, pp. 89–105.

(209) ——— On the effect of continued administration of certain poisons to the domestic fowl, with special reference to the progeny. Amer. Phil. Soc. Proc., 55 (1916), No. 3, pp. 243–258; Natl. Acad. Sci. Proc., 2 (1916), No. 7, pp. 380–384; abs. in Me. Sta. Bul. 257 (1916), pp. 352–354.

(210) ——— Some effects of the continued administration of alcohol to the domestic fowl, with special reference to the progeny. Natl. Acad. Sci. Proc., 2 (1916), No. 12, pp. 675–683.

(211) ——— The separate inheritance of plumage pattern and pigmentation in Plymouth Rocks. Pract. Husb. Maine, 6 (1916), No. 2, pp. 567, 568; abs. in Me. Sta. Bul. 257 (1916), p. 354.

(212) ——— On the differential effect of certain calcium salts upon the rate of growth of the two sexes of the domestic fowl. Science, 44 (1916), No. 1141, pp. 687, 688; abs. in Me. Sta. Bul. 268 (1917), p. 304.

(213) ——— The experimental modification of germ cells.—I, General plan of experiments with ethyl alcohol and certain related substances. Jour. Expt. Zool., 22 (1917), No. 1, pp. 125–164; abs. in Me. Sta. Bul. 268 (1917), pp. 297–299.

Maine Station—Continued.

(214) Pearl, R. The experimental modification of germ cells.—II, The effect upon the domestic fowl of the daily inhalation of ethyl alcohol and certain related substances. Jour. Expt. Zool., 22 (1917, No. 1, pp. 165–186; abs. in Me. Sta. Bul. 268 (1917), p. 299.

(215) ——— The experimental modification of germ cells.—III, The effect of parental alcoholism, and certain other drug intoxications, upon the progeny. Jour. Expt. Zool., 22 (1917), No. 2, pp. 241–310; abs. in Me. Sta. Bul. 268 (1917), pp. 300–303.

(216) ——— The selection problem. Amer. Nat., 51 (1917), No. 602, pp. 65–91.

(217) ——— The probable error of a Mendelian class frequency. Amer. Nat., 51 (1917), No. 603, pp. 144–156.

(218) ——— The probable error of a difference and the selection problem. Genetics, 2 (1917), No. 1, pp. 78–81; abs. in Me. Sta. Bul. 268 (1917), p. 303.

(219) ——— Some commonly neglected factors underlying the stock breeding industry. Me. Sta. Bul. 258 (1917), pp. 28.

(220) ——— Factors influencing the sex ratio in the domestic fowl. Science, 46 (1917), No. 1183, p. 220.

(221) ——— and Boring, A. M. Some physiological observations regarding plumage patterns. Science, 39 (1914), No. 995, pp. 143, 144; abs. in Me. Sta. Bul. 234 (1914), pp. 281–283.

(222) ——— and Curtis, M. R. Dwarf eggs of the domestic fowl. Me. Sta. Bul. 255 (1916), pp. 289–328.

(223) ——— and Gowen, J. W. On the refractive index of the serum in a guinea-chicken hybrid. Soc. Expt. Biol. and Med. Proc., 12 (1914), No. 2, p. 48; abs. in Me. Sta. Bul. 245 (1915), pp. 292, 293.

(224) ——— and M. D. Data on variation in the comb of the domestic fowl. Biometrika, 6 (1909), No. 4, pp. 420–432.

(225) ——— and Miner, J. R. Variation of Ayrshire cows in the quantity and fat content of their milk. Jour. Agr. Research [U. S.], 17 (1919), No. 6, pp. 285–322; abs. in Me. Sta. Bul. 279 (1919), pp. 57–64.

(226) ——— and Surface, F. M. A biometrical study of egg production in the domestic fowl.—I, Variation in annual egg production. U. S. Dept. Agr., Bur. Anim. Indus. Bul. 110 (1909), pt. 1, pp. 80.

(227) ——— ——— A biometrical study of egg production in the domestic fowl.—II, Seasonal distribution of egg production. U. S. Dept. Agr., Bur. Anim. Indus. Bul. 110 (1911), pt. 2, pp. 81–170.

Maine Station—Continued.

(228) Pearl, R., and Surface, F. M. A biometrical study of egg production in the domestic fowl.—III. Variation and correlation in the physical characters of the egg. U. S. Dept. Agr., Bur. Anim. Indus. Bul. 110 (1913), pt. 3, pp. VI + 171–241.

(229) Curtis, M. R. A biometrical study of egg production in the domestic fowl.—IV, Factors influencing the size, shape, and physical constitution of eggs. Arch. Entwickl. Mech. Organ., 39 (1914), pt. 2–3, pp. 217–327.

(230) Pearl, R., and Surface, F. M. Selection index numbers and their use in breeding. Amer. Nat., 43 (1909), No. 511, pp. 385–400.

(231) ——— ——— Data on the inheritance of fecundity obtained from the records of egg production of the daughters of "200-egg" hens. Me. Sta. Bul. 166 (1909), pp. 49–84.

(232) ——— ——— Is there a cumulative effect of selection? Ztschr. Induktive Abstam. u. Vererbungslehre 2 (1909), No. 4, pp. 257–275.

(233) ——— ——— On the inheritance of the barred color pattern in poultry. Arch. Entwickl. Mech. Organ., 30 (1910), pt. 1, pp. 45–61.

(234) ——— ——— Poultry notes, 1909. Me. Sta. Bul. 179 (1910), pp. 65–124.

(235) ——— ——— Further data regarding the sex-limited inheritance of the barred color pattern in poultry. Science, 32 (1910), No. 833, pp. 870–874.

(236) Woods, C. D. Controlling sex in calves. New England Homestead, 66 (1913), No. 25, p. 748.

Massachusetts Station.

(237) Goodale, H. D. Sex and its relation to the barring factor in poultry. Science, 29 (1909), No. 756, pp. 1004, 1005.

(238) ——— Some results of castration in ducks. Biol. Bul. Mar. Biol. Lab. Woods Hole, 20 (1910), No. 1, pp. 35–66.

(239) ——— Sex-limited inheritance and sexual dimorphism in poultry. Science, 33 (1911), No. 859, pp. 939, 940.

(240) ——— Castration in relation to the secondary sexual characters of Brown Leghorns. Amer. Nat., 47 (1913), No. 555, pp. 159–169.

(241) ——— Additional data on effect of castration in domestic fowl. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 1 (1915), No. 3, pp. 23, 24.

(242) ——— On the rythm of egg production. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 1 (1915), No. 3, pp. 18, 19.

Massachusetts Station—Continued.

(243) Goodale, H. D. Further developments in ovariotomized fowl. Biol. Bul. Mar. Biol. Lab. Woods Hole, 30 (1916), No. 4, pp. 286–293.

(244) ——— Gonadectomy in relation to the secondary sexual characters of some domestic birds. Carnegie Inst. Wash. Pub. 243 (1916), pp. 52; abs. in Jour. Roy. Micros. Soc., No. 1 (1917), pp. 106, 107.

(245) ——— A feminized cockerel. Jour. Expt. Zool., 20 (1916), No. 3, pp. 421–428.

(246) ——— Further data on the relation between the gonads and the soma of some domestic birds. Abs. in Anat. Rec., 11 (1917), No. 6, pp. 512–514.

(247) ——— A study of broodiness in the Rhode Island Red breed of domestic fowl. Abs. in Anat. Rec., 11 (1917), No. 6, pp. 533, 534.

(248) ——— The feminization of male birds. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 3 (1917), No. 9, pp. 68, 69, 70.

(249) ——— Crossing over in the sex chromosome of the male fowl. Science, 46 (1917), No. 1183, p. 213.

(250) ——— Concerning the summer plumage of the drake. Abs. in Anat. Rec., 14 (1918), No. 1, pp. 92, 93.

(251) ——— Internal factors influencing egg production in the Rhode Island Red breed of domestic fowl. Amer. Nat., 52 (1918), Nos. 614, pp. 65–94; 616–617, pp. 209–232; 618–619; pp. 301–321.

(252) ——— Feminized male birds. Genetics, 3 (1918), No. 3, pp. 276–299.

(253) ——— Interstitial cells in the gonads of domestic fowl. Anat. Rec., 16 (1919), No. 4, pp. 247–250.

(254) ——— Is the inheritance of egg production an insoluble problem? Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 5 (1919), No. 10, pp. 73, 74.

(255) ——— Practical results from studies on egg production. Mass. Sta. Bul. 191 (1919), pp. 97–104.

(256) ——— Concerning hen feathering. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 7 (1920), No. 2, pp. 14, 15.

(257) ——— Intertubular tissue in the testes of certain birds. Amer. Nat., 58 (1924), No. 654, pp. 92, 93.

(258) ——— and MacMullen, G. The bearing of ratios on theories of the inheritance of winter egg production. Jour. Expt. Zool., 28 (1919), No. 1, pp. 83–124.

(259) ——— and Morgan, T. H. Heredity of tricolor in guinea-pigs. Amer. Nat., 47 (1918), No. 558, pp. 321–348.

Massachusetts Station—Continued.

(260) GOODALE, H. D., and NONIDEZ, J. F. Luteal cells and hen-feathering. Amer. Nat., 58 (1924), No. 654, pp. 91, 92.

(261) ———, SANBORN, R., and WHITE, D. Broodiness in domestic fowl.—Data concerning its inheritance in the Rhode Island Red breed. Mass. Sta. Bul. 199 (1920), pp. 93–116.

(262) HARRIS, J. A., and GOODALE, H. D. The correlation between the egg production of the various periods of the year in the Rhode Island Red breed of domestic fowl. Genetics, 7 (1922), No. 5, pp. 446–465.

(263) HAYS, F. A. Inbreeding the Rhode Island Red fowl with special reference to winter egg production (preliminary report). Amer. Nat., 58 (1924), No. 654, pp. 43–59.

(264) ——— and SANBORN, R. The inheritance of fertility and hatchability in poultry. Mass. Sta. Tech. Bul. 6 (1924), pp. 19–42.

(265) RUCKER, E. H. Sex-linked inheritance of [spangling in poultry]. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 3 (1916), No. 1, pp. 6, 7.

Michigan Station.

(266) FOREMAN, E. C. Inheritance of higher fecundity and the mode of transmission. Mich. Sta. Rpt. 1922, pp. 231, 232.

Minnesota Station.

(267) ECKLES, C. H. Effect of delayed breeding on milk production. Hoard's Dairyman, 65 (1923), No. 7, pp. 230, 263.

Mississippi Station.

(268) MOORE, J. S. Influence of heredity on sex control. Jersey Bul. and Dairy World, 43 (1924), No. 16, pp. 696, 697.

Missouri Station.

(269) ANON. A study of sex-linked inheritance in poultry. Mo. Sta. Bul. 117 (1914), pp. 430, 431.

(270) BRODY, S., RAGSDALE, A. C., and TURNER, C. W. The rate of decline of milk secretion with the advance of the period of lactation. Jour. Gen. Physiol., 5 (1923), No. 4, pp. 441–444.

(271) ——— ——— ——— The effect of gestation on the rate of decline of milk secretion with the advance of the period of lactation. Jour. Gen. Physiol., 5 (1923), No. 6, pp. 777–782.

(272) LEFEVRE, G. Sex-linked inheritance of spangling in poultry. Abs. in Anat. Rec., 11 (1917), No. 6, pp. 499, 500.

(273) ——— Mendelian inheritance in poultry. Abs. in Mo. Sta. Bul. 147 (1917), pp. 47, 48.

Missouri Station—Continued.

(274) LEFEVRE, G. Sex-linked inheritance in poultry. Mo. Sta. Bul. 189 (1921), pp. 58, 59.

(275) ——— and RUCKER, E. H. Investigation in Mendelian inheritance. Mo. Sta. Bul. 141 (1916), p. 42.

(276) ——— ——— The inheritance of spangling in poultry. Genetics, 8 (1923), No. 4, pp. 367–389.

(277) TURNER, C. W. The effect of pregnancy on growth and milk production. Breeder's Gaz., 83 (1923), No. 12, p. 395.

(278) ——— The relation between age and production of Holstein-Friesian cows. Holstein-Friesian World. 20 (1923), No. 12, p. 557.

Nebraska Station.

(279) ANON. A study of the influence of certain physical qualities of eggs, mainly size and specific gravity, on the fertility, hatching power, and size and rate of growth of chicks. Nebr. Sta. Rpt. 1921, p. 25.

(280) HALBERSLEBEN, D. L., and MUSSEHL, F. E. Relation of egg weight to chick weight at hatching. Poultry Sci., 1 (1922), No. 4, pp. 143, 144.

(281) MUSSEHL, F. E. Sex ratios in poultry. Poultry Sci., 3 (1923–24), No. 2, pp. 72, 73.

(282) ——— and HALBERSLEBEN, D. L. Influence of the specific gravity of hens' eggs on fertility, hatching power, and growth of chicks. Jour. Agr. Research [U. S.], 23 (1923), No. 9, pp. 717–720.

New Hampshire Station.

(283) ARKELL, T. R. [Inheritance in sheep.] N. H. Sta. Bul. 151 (1910), pp. 32–38.

(284) ——— Some data on the inheritance of horns in sheep. N. H. Sta. Bul. 160 (1912), p. 35.

(285) RITZMAN, E. G. Mendelism of short ears in sheep. Jour. Agr. Research [U. S.], 6 (1916), No. 20, pp. 797, 798.

(286) ——— Breeding earless sheep. Jour. Heredity, 11 (1920), No. 5, pp. 238–240; also in N. H. Sta. Sci. Contrib. 17 (1921), pp. 238–240.

(287) ——— Sheep breeding experiment. N. H. Sta. Bul. 203 (1922), pp. 9, 10.

(288) ——— Sheep breeding experiments. N. H. Sta. Bul. 208 (1923), pp. 10, 11.

(289) ——— Inheritance of size and conformation in sheep. N. H. Sta. Tech. Bul. 25 (1923), pp. 36.

(290) ——— Sheep breeding. N. H. Sta. Bul. 212 (1924), p. 16.

(291) ——— and DAVENPORT, C. B. Family performance as a basis for selection in sheep. Jour. Agr. Research [U. S.], 10 (1917), No. 2, pp. 93–97.

New Hampshire Station—Continued.

(292) RITZMAN, E. G., and DAVENPORT, C. B. A comparison of some traits of conformation of Southdown and Rambouillet sheep and of their F_1 hybrids, with preliminary data and remarks on variability in F_2. N. H. Sta. Tech. Bul. 15 (1920), pp. 32.

New Jersey Stations.

(293) HARRIS, J. A., and LEWIS, H. R. The correlation between first- and second-year egg production in the domestic fowl. Genetics, 7 (1922), No. 3, pp. 274–318.

(294) ——— ——— The interrelationship of the egg records of various periods during the first and second year of the White Leghorn fowl. Poultry Sci., 1 (1922), No. 4, pp. 97–107.

(295) ——— ——— The correlation between the monthly record of the first year and the annual record of the second year, with special reference to culling for second year production. Poultry Sci., 1 (1922), No. 5, pp. 145–150.

(296) ——— ——— The "winter cycle" in the fowl. Science, 56 (1922), No. 1443, pp. 230, 231.

(297) ——— ——— The correlation between the time of beginning and the time of cessation of laying in the first and second laying year in the domestic fowl. Genetics, 8 (1923), No. 1, pp. 37–74.

(298) ——— ——— Biometric considerations on the inheritance of fecundity in the White Leghorn fowl. Poultry Sci., 2 (1923), No. 3, pp. 65–74.

(299) HERVEY, G. W. A note on the inheritance of egg production in the Leghorn fowl. Poultry Sci., 3 (1924), No. 4, pp. 134, 135.

(300) LEWIS, H. R. Variation in and inheritance of egg shell color. N. J. Stas. Rpt. 1921, pp. 121–123.

(301) ——— and CLARK, A. L. Breeding experiments [with poultry]. N. J. Stas. Rpt. 1913, pp. 249–259.

(302) ——— and THOMPSON, W. C. Breeding problems [with poultry]. N. J. Stas. Rpt. 1916, pp. 142–147.

New York Cornell Station.

(303) ALLEN, C. L. The effect of the age of sire and dam on the quality of offspring in dairy cows. Jour. Heredity, 13 (1922), No. 4, pp. 167–176; also in Holstein-Friesian World, 20 (1923), No. 17, pp. 817–819.

(304) BENJAMIN, E. W. A study of selections for the size, shape, and color of hens' eggs. N. Y. Cornell Sta. Mem. 31 (1920), pp. 195–312.

(305) GUTHRIE, C. C. On graft hybrids. Amer. Breeders Assoc. Proc., 6 (1909), pp. 356–373.

Ohio Station.

(306) HAYDEN, C. C. A case of twinning in dairy cattle. Ohio Sta. Mo. Bul. 7 (1922), No. 3–4, pp. 54–57.

Oklahoma Station.

(307) ANON. A study of inheritance of character in sheep. Okla. Sta. Rpt. 1921, pp. 16, 17.

(308) ——— [The effect of long-continued feeding of cottonseed meal, linseed meal, and tankage on the number and vitality of the spermatozoa of hogs.] Okla. Sta. Rpt. 1921, pp. 27–29.

(309) LEWIS, L. L. The vitality of reproductive cells. Okla. Sta. Bul. 96 (1911), pp. 47.

(310) PAYNE, L. F. Vitality and activity of sperm cells and artificial insemination of the chicken. Okla. Sta. Circ. 30 (1914), pp. 8.

(311) RUSSELL, S. F. Inheritance of characters in sheep. Okla. Sta. Bul. 126 (1919), pp. 22.

Oregon Station.

(312) DRYDEN, J. Inbreeding, its effect on vigor and egg laying Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 1 (1915), No. 3, p. 19.

(313) ——— Egg-laying characteristics of the hen. Oreg. Sta. Bul. 180 (1921), pp. 96.

Pennsylvania Station.

(314) SEVERSON, B. O. A study in cross-breeding Delaine-Merrino ewes with mutton rams and cross-bred rams of the F_1 generation. Pa. Sta. Rpt. 1917, pp. 212–268.

(315) TOMHAVE, W. H., and MCDONALD, C. W. Cross breeding Delaine Merino ewes with purebred mutton rams. Pa. Sta. Bul. 163 (1920), pp. 19.

Porto Rico Station.

(316) RITZMAN, E. G. Report of the animal husbandman. P. R. Sta. Rpt. 1913, pp. 30–34.

Rhode Island Station.

(317) ANON. Inheritance studies with poultry. R. I. Sta. Bul. 193 (1923), p. 15.

(318) COLE, L. J. Breeding work with pigeons. R. I. Sta. Rpt. 1908, pp. 200–302.

(319) ——— Studies on inheritance in pigeons.—I. Hereditary relations of the principal colors. R. I. Sta. Bul. 158 (1914), pp. 309–380.

(320) ——— and KIRKPATRICK, W. F. Sex ratios in pigeons, together with observations on the laying, incubation, and hatching of the eggs. R. I. Sta. Bul. 162 (1915), pp. 461–512; also in Natl. Acad. Sci. Proc., 1 (1915), No. 6, pp. 354–356.

(321) HADLEY, P. B. Studies on inheritance in poultry.—I, The constitution of the White Leghorn breed. R. I. Sta. Bul. 155 (1913), pp. 149–216.

Rhode Island Station—Continued.

(322) Hadley, P. B. Studies on inheritance in poultry.—II. The factor for black pigmentation in the White Leghorn breed. R. I. Sta. Bul. 161 (1914), pp. 447–460.

(323) ——— The presence of the barred plumage patterns in the White Leghorn breed of fowls. Amer. Nat., 47 (1913), No. 559, pp. 418–428.

(324) ——— Studies on fowl cholera.—III, The inheritance in rabbits of immunity to infection with the bacterium of fowl cholera. R. I. Sta. Bul. 157 (1914), pp. 283–307.

(325) ——— Egg-weight as a criterion of numerical production in the domestic fowl. Amer. Nat., 53 (1919), No. 628, pp. 377–393.

(326) ——— and Caldwell, D. W. Studies on the inheritance of egg-weight in the domestic fowl.—I, Normal distribution of egg-weight. R. I. Sta. Bul. 181 (1920), pp. 64.

Texas Station.

(327) Anon. Brahma-Hereford cross. Tex. Sta. Rpt. 1921, pp. 8, 9.

(328) ——— An hereditary notch in the ears of Jersey cattle. Jour. Heredity, 13 (1922), No. 1, pp. 8–13.

(329) ——— What are the chief results of crossbreeding? Breeder's Gaz., 83 (1923), No. 3, p. 74.

(330) ——— Twinning in Brahma cattle. Jour. Heredity, 15 (1924), No. 1, pp. 25–27.

(331) ——— "Double ears" in Brahma cattle. Jour. Heredity, 15 (1924), No. 2, pp. 93–96.

(332) ——— and Jones, J. M. The influence of individuality, age, and season upon the weights of fleeces produced by range sheep. Tex. Sta. Bul. 311 (1923), pp. 45.

(333) Sherwood, R. M. Correlation between external body characters and annual egg production in White Leghorn fowls. Tex. Sta. Bul. 295 (1922), pp. 14.

(334) Stangel, W. L. A fertile mare mule. Breeder's Gaz., 85 (1924), No. 3, p. 77.

(335) Templeton, G. S. Unusual color inheritance. Jour. Heredity, 14 (1923), No. 1, pp. 39, 40.

Utah Station.

(336) Ball, E. D., Alder, B., and Egbert, A. D. Breeding for egg production.—Part I, A Study of annual and total production. Utah Sta. Bul. 148 (1916), pp. 60.

(337) ——— ——— Breeding for egg production.—Part II, Seasonal distribution of egg production. Utah Sta. Bul. 149 (1917), pp. 71.

Vermont Station.

(338) Rich, F. A. Concerning blood complement. Vt. Sta. Bul. 230 (1923), pp. 24.

Washington Station.

(339) Woodward, E. G. The effect of exercise and feed upon the vitality and breeding ability of bulls. Wash. Sta. Bul. 158 (1920), p. 20.

West Virginia Station.

(340) Atwood, H., and Snyder, H. A hen with two ovaries? Poultry Sci., 2 (1922–23), No. 2, pp. 59–61.

Wisconsin Station.

(341) Anon. The germ cells. Wis. Sta. Bul. 339 (1922), pp. 118–120.

(342) ——— Inactive ovaries cause of male plumage in hens. Wis. Sta. Bul. 352 (1923), pp. 25–27.

(343) Bachhuber, L. J. The behavior of the accessory chromosomes and of the chromatoid body in the spermatogenesis of the rabbit. Biol. Bul. Mar. Biol. Lab. Woods Hole, 30 (1916), No. 4, pp. 294–310.

(344) Cole, L. J. A case of sex-linked inheritance in the domestic pigeon. Science, 36 (1912), No. 919, pp. 190–192.

(345) ——— Effect of poison on germ cells. Wis. Sta. Bul. 250 (1915), pp. 44–46.

(346) ——— Twinning in cattle, with special reference to the free martin. Abs. in Science, 43 (1916), No. 1101, pp. 177, 178.

(347) ——— Determinate and indeterminate laying cycles in birds. Abs. in Anat. Rec., 11 (1917), No. 6, pp. 504, 505.

(348) ——— A defect of hair and teeth in cattle, probably hereditary. Jour. Heredity, 10 (1919), No. 7, pp. 303–306.

(349) ——— An early family history of color blindness. Jour. Heredity, 10 (1919), No. 8, pp. 372–374.

(350) ——— Inheritance of milk and meat production in cattle. Wis. Sta. Bul. 319 (1920), pp. 53, 54.

(351) ——— The inbreeding problem in the light of recent experimentation. Amer. Soc. Anim. Prod. Proc., Nov., 1921, pp. 30–32.

(352) ——— The Wisconsin experiment in crossbreeding cattle. U. S. Dept. Agr., Dairy Div., World's Dairy Cong. Proc., 1923, vol. 2, pp. 1383–1389.

(353) ——— Inheritance of milk and meat production in cattle. Wis. Sta. Bul. 352 (1923), p. 27.

(354) ——— and Bachhuber, L. J. The effect of lead on the germ cells of the male rabbit and fowl as indicated by their progeny. Soc. Expt. Biol. and Med. Proc., 12 (1914), No. 1, pp. 24–29.

(355) ——— and Halpin, J. G. Experiments show inbreeding effects. Wis. Sta. Bul. 339 (1922), pp. 116–118.

(356) ——— and Ibsen, H. L. Physiology of reproduction. Wis. Sta. Bul. 250 (1915), p. 46.

Wisconsin Station—Continued.

(357) COLE, L. J., and IBSEN, H. L. Inheritance of congenital palsy in guinea-pigs. Amer. Nat., 54 (1920), No. 631, pp. 130–151.

(358) ——— and JONES, S. VAN H. The occurrence of red calves in black breeds of cattle. Wis. Sta. Bul. 313 (1920), pp. 36.

(359) ——— and LIPPINCOTT, W. A. The relation of plumage to ovarian condition in a Barred Plymouth Rock pullet. Biol. Bul. Mar. Biol. Lab. Woods Hole, 36 (1919), No. 3, pp. 167–182.

(360) ——— and STEELE, D. G. A waltzing rabbit. Jour. Heredity, 13 (1922), No. 7, pp. 291–294.

(361) ——— and WRIGHT, W. H. Application of the pure-line concept to bacteria. Jour. Infect. Diseases, 19 (1916), No. 2, pp. 209–221.

(362) IBSEN, H. L. Tricolor inheritance.—I, The tricolor series in guinea-pigs. Genetics, 1 (1916), No. 3, pp. 287–309.

(363) ——— Tricolor inheritance.—II, The basset hound. Genetics, 1 (1916), No. 4, pp. 367–376.

(364) ——— Tricolor inheritance.—III, Tortoiseshell cats. Genetics, 1 (1916), No. 4, pp. 377–386.

(365) ——— Tricolor inheritance.—IV, The triple allelomorphic series in guinea pigs. Genetics, 4 (1919), No. 6, pp. 597–606.

(366) ——— Synthetic pink-eyed self white guinea-pigs. Amer. Nat., 53 (1919), No. 625, pp. 120–130.

(367) ——— Linkage in rats. Amer. Nat., 54 (1920), No. 630, pp. 61–67.

(368) ——— Some genetic experiments with guinea-pigs and rats. Amer. Soc. Anim. Prod. Proc., 1922, pp. 99–101.

Wisconsin Station—Continued.

(369) IBSEN, H. L., and STEIGLEDER, E. Evidence for the death in utero of the homozygous yellow mouse. Amer. Nat., 51 (1917), No. 612, pp. 740–752.

(370) JONES, S. VAN H. Inheritance of silkiness in fowls. Jour. Heredity, 12 (1921), No. 3, pp. 117–128.

(371) ——— and ROUSE, J. E. The relation of age of dam to observed fecundity in domesticated animals.—I, Multiple births in cattle and sheep. Jour. Dairy Sci., 3 (1920), No. 4, pp. 260–290.

(372) KUHLMAN, A. H. Jersey-Angus cattle. Jour. Heredity, 6 (1915), No. 2, pp. 68–72.

(373) LLOYD-JONES, O. Studies on inheritance in pigeons.—II, A microscopical and chemical study of the feather pigments. Jour. Expt. Zool., 18 (1915), No. 3, pp. 453–509.

(374) COLE, L. J., and KELLEY, F. J. Studies on inheritance in pigeons.—III, Descriptions and linkage relations of two sex-linked characters. Genetics, 4 (1919), No. 2, pp. 183–203.

(375) JONES, S. VAN H. Studies on inheritance in pigeons.—IV, Checks and bars and other modifications of black. Genetics, 7 (1922), No. 5, pp. 466–507.

Wyoming Station.

(376) HELLER, L. L. Reversion in sheep. Jour. Heredity, 6 (1915), No. 10, p. 480.

(377) HILL, J. A. Studies in the variation and correlation of fleeces from range sheep. Wyo. Sta. Bul. 127 (1921), pp. 39–52.

(378) HULTZ, F. S. Problems of heredity in sheep. Wyo. Sta. Rpt. 1923, pp. 53–55.

PUBLICATIONS OF THE STATIONS, 1924

The following is a classification of station publications received by the Office of Experiment Stations during the year. Only publications of the regular series issued by the stations are listed. It has not been practicable to list other publications, but it may be of interest to note that during the period covered by this report approximately 60 papers originating in the experiment stations were published or accepted for publication in the Journal of Agricultural Research.

AGRICULTURAL CHEMISTRY—AGROTECHNY

Studies with phytosterols: Phytosterols of corn oil, cottonseed oil and linseed oil. R. J. Anderson and M. G. Moore. (N. Y. State Sta. Tech. Bul. 95, pp. 16. Aug., 1923.)

Chemical studies of grape pigments: The anthocyans in Norton and Concord grapes R. J. Anderson. (N. Y. State Sta. Tech. Bul. 96, pp. 19. Aug. 1923.)

A chemical study of legumes and other forage crops of western Oregon. J. S. Jones and D. E. Bullis. (Oreg. Sta. Bul. 197, pp. 24. July, 1923.)

Miscellaneous soil samples—Their value. R. E. Neidig and G. R. McDole. (Idaho Sta. Circ. 33, pp. 4. Jan., 1924.)

Biochemical oxidation of sulfur and its significance to agriculture. J. S. Joffe. (N. J. Stas. Bul. 374, pp. 91, figs. 4. Dec., 1922.)

Simplified apparatus and technique for the electrometric determination of hydrogen ion concentration in milk and other biological liquids. F. E. Rice and A. J. Rider. (N. Y. Cornell Sta. Mem. 16, pp. 66, fig. 1. Apr., 1923.)

Vinegar fermentation and home production of cider vinegar. A. R. Lamb and E. Wilson. (Iowa Sta. Bul. 218, pp. 14. Aug., 1923.)

Fruit jellies.—II, The role of sugar. L. W. Tarr and G. L. Baker. Del. Sta. Bul. 136, pp. 29. Mar., 1924.)

Application of the principles of jelly making to Hawaiian fruits. J. C. Ripperton. (Hawaii Sta. Bul. 47, pp. 24, pl. 1. June, 1923.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander and H. H. Shepard. (Mass. Sta. Met. Buls. 414–425, pp. 4 each. June, 1923—May, 1924.)

SOILS

Liming Wisconsin soils. A. R. Whitson, G. Richards, and H. W. Ullsperger. (Wis. Sta. Bul. 361, pp. 24, figs. 13. Feb., 1924.)

Experiments on the reclamation of alkali soils by leaching with water and gypsum. P. L. Hibbard. (Calif. Sta. Tech. Paper 9, pp. 14, Aug., 1923.)

Controlling soil moisture for vegetable crops in Missouri. J. T. Rosa. (Mo. Sta. Bul. 204, pp. 8, figs. 3. June, 1923.)

The seasonal variation of the soil moisture in a walnut grove in relation to the hygroscopic coefficient. L. D. Batchelor and H. S. Reed. (Calif. Sta. Tech. Paper 10, pp. 31, figs. 7. Sept., 1923.)

The soils of Arkansas. N. Nelson, W. H. Sachs, and R. H. Austin. (Ark. Sta. Bul. 187, pp. 83, pl. 1, figs. 24. June, 1923.)

The Iowa system of soil management. W. H. Stevenson and P. E. Brown. (Iowa Sta. Bul. 213, pp. 289–318, figs. 13. May, 1923.)

Management of the light colored clay and silt loam soils. A. T. Wiancko. (Ind. Sta. Circ. 115, pp. 20, figs. 5. Jan., 1924.)

Soil experiments on the gravelly Ozark upland. M. F. Miller and F. L. Duley. (Mo. Sta. Bul. 202, pp. 22, figs. 13. Mar., 1923.)

Soil experiments on the brown silt loam of the Ozark border region. M. F. Miller and F. L. Duley. (Mo. Sta. Bul. 203, pp. 24, figs. 7. Apr., 1923.)

A peculiar soil condition in the San Luis Valley. W. P. Headden. (Colo. Sta. Bul. 286, pp. 15, figs. 3. May, 1923.)

Sandy soils of southern peninsula of Michigan. M. M. McCool and J. O. Veatch. (Mich. Sta. Spec. Bul. 128, pp. 31, figs. 17. Jan., 1924.)

Livingston County soils. J. G. Mosier, S. V. Holt, F. A. Fisher, E. E. DeTurk, and H. J. Snider. (Ill. Sta. Soil Rpt. 25, pp. 55, pls., 4, figs. 3. June, 1923.)

Grundy County soils. R. S. Smith, E. E. DeTurk, F. C. Bauer, and L. H. Smith. (Ill. Sta. Soil Rpt. 26, pp. 66, pls. 2, figs. 6. Mar., 1924.)

Soil survey of Iowa.—Marshall County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 25, pp. 64, pl. 1, figs. 14. July, 1922.)

Soil survey of Iowa.—Madison County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 26, pp. 56, pl. 1, figs. 11. June, 1922.)

Soil survey of Iowa.—Adair County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 27, pp. 62, pl. 1, figs. 18. July, 1922.)

Soil survey of Iowa.—Cedar County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 28, pp. 63, pl. 1, figs. 14. June, 1922.)

Soil survey of Iowa.—Mahaska County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 29, pp. 72, pl. 1, figs. 13. Mar., 1923.)

Soil survey of Iowa.—Fayette County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 30, pp. 70, pls. 2, figs. 13. Mar., 1923.)

Soil survey of Iowa.—Wright County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 31, pp. 64, pl. 1, figs. 11. June, 1923.)

Soil survey of Iowa.—Johnson County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 32, pp. 72, pls. 2, figs. 14. June, 1923.)

Soils of Sheridan County.—Preliminary report. L. F. Gieseker. (Mont. Sta. Bul. 158, pp. 20, pls. 4. Apr., 1923.)
The influence of nitrogen in soil on azofication. J. E. Greaves and D. H. Nelson. (Utah Sta. Bul. 185, pp. 23. July, 1923.)
Nitrification and acidity in the muck soils of North Carolina. L. G. Willis. (N. C. Sta. Tech. Bul. 24, pp. 14. Nov., 1923.)
"Active" aluminum as a factor detrimental to crop production in many acid soils. P. S. Burgess and F. R. Pember. (R. I. Sta. Bul. 194, pp. 40, figs. 6. June, 1923.)
Erosion and surface runoff under different soil conditions. F. L. Duley and M. F. Miller. (Mo. Sta. Research Bul. 63, pp. 50, figs. 22. Dec., 1923.)
Controlling surface erosion of farm lands. F. L. Duley. (Mo. Sta. Bul. 211, pp. 23, figs. 17. Apr., 1924.)
A study of alkali and plant food under irrigation and drainage. C. W. Botkin. (N. Mex. Sta. Bul. 136, pp. 44, figs. 11. Apr., 1923.)
Some physical and chemical properties of several soil profiles. L. C. Wheeting. (Mich. Sta. Tech. Bul. 62, pp. 31, figs. 6. Jan., 1924.)
Chemical analyses of Montana soils. E. Burke and R. M. Pinckney. (Mont. Sta. Bul. 159, pp. 13. Aug., 1923.)
The chemical nature of a colloidal clay. R. Bradfield. (Mo. Sta. Research Bul. 60, pp. 60, figs. 7. June, 1923.)

FERTILIZERS

Standard fertilizer formulas and their use. G. S. Fraps. (Tex. Sta. Circ. 31, pp. 7. Sept., 1923.)
Fertilizers for Delaware crops and soils. C. A. McCue and G. L. Schuster. (Del. Sta. Circ. 12, pp. 12, figs. 11. July, 1923.)
Testing fertilizers for Missouri farmers, 1923. L. D. Haigh. (Mo. Sta. Bul. 209, pp. 55, figs. 2. Feb., 1924.)
The comparative crop effect of fertilizer chemicals, cow manure with straw bedding or with planer-shavings bedding, and of the latter supplemented with phosphorus or potassium. B. L. Hartwell, S. C. Damon, and F. K. Crandall. (R. I. Sta. Bul. 196, pp. 11. Nov., 1923.)
"Amo-phos:" Its effects upon seed germination and plant growth. D. G. Coe. (N. J. Stas. Bul. 375, pp. 102, figs. 32. Jan., 1923.)
The effect of heat upon the availability of phosphorus in basic phosphate rock. A. G. McCall and C. P. Wilhelm. (Md. Sta. Bul. 260, pp. 101–120, figs. 3. Dec., 1923.)
Marls for liming soils. S. C. Jones. (Ky. Sta. Circ. 32, pp. 12, figs. 3. Apr., 1924.)
Sulfur in relation to soil fertility. W. L. Powers. (Oreg. Sta. Bul. 199, pp. 45, figs. 17. Dec., 1923.)

BOTANY AND PLANT NUTRITION

Some mutual effects on soil and plant induced by added solutes. J. S. Burd and J. C. Martin. (Calif. Sta. Tech. Paper 13, pp. 27, figs. 3. Dec., 1923.)
Effect of salts on the intake of inorganic elements and on the buffer system of the plant. D. R. Hoagland and J. C. Martin. (Calif. Sta. Tech. Paper 8, pp. 26, figs. 5. July, 1923.)
The effect of the plant on the reaction of the culture solution. D. R. Hoagland. (Calif. Sta. Tech. Paper 12, pp. 16. Nov., 1923.)
Relationships between hydrogen ion, hydroxyl ion, and salt concentrations, and the growth of seven soil molds. H. W. Johnson. (Iowa Sta. Research Bul. 76, pp. 307–344, figs. 8. Jan., 1923.)
Is there normally a cross transfer of foods, water, and mineral nutrients in woody plants? E. C. Auchter. (Md. Sta. Bul. 257, pp. 31–62. Sept., 1923.)
Catalese activity in dormant apple twigs.—Its relation to the condition of the tissue, respiration, and other factors. A. J. Heinicke. (N. Y. Cornell Sta. Mem. 74, pp. 33, fig. 1. Mar., 1924.)
The morphology of the double kernel in *Zea mays* var. *polysperma*. Mildred E. Stratton. (N. Y. Cornell Sta. Mem. 69, pp. 18, figs. 8. June, 1923.)
The parasitism of *Colletotrichum lindemuthianum*. J. G. Leach. (Minn. Sta. Tech. Bul. 14, pp. 41, pls. 8, figs. 6. Mar., 1923.)
Studies on the parasitism of *Helminthosporium sativum*. J. J. Christensen. (Minn. Sta. Tech. Bul. 11, pp. 42, pls. 10, figs. 2. Nov., 1922.)
Major plant communities of North Carolina. B. W. Wells. (N. C. Sta. Tech. Bul. 25, pp. 20, figs. 15. Apr., 1924.)

BACTERIOLOGY

Methods of gram staining. G. J. Hucker and H. J. Conn. (N. Y. State Sta. Tech. Bul. 93, pp. 37. Mar., 1923.)
Studies on *Streptococcus paracitrovorus* group. B. W. Hammer and M. P. Baker. (Iowa Sta. Research Bul. 81, pp. 17–36. July, 1923.)
Factors influencing the activity of spore-forming bacteria in soil. J. S. Joffe and H. J. Conn. (N. Y. State Sta. Tech. Bul. 97, pp. 21. Oct., 1923.)
Flat sours.—Part I, An interesting thermophile encountered in canned string beans. Z. N. Wyant. Part II, Bacteriological studies of flat sours of cold packed canned peas. Z. N. Wyant and R. L. Tweed. (Mich. Sta. Tech. Bul. 59, pp. 29. Feb., 1923.)
Bacterial decomposition of olives during pickling. W. V. Cruess and E. H. Guthier. (Calif. Sta. Bul. 368, pp. 15, figs. 5. July, 1923.)

GENETICS

Hybridization of *Vitis rotundifolia*.—Inheritance of anatomical stem characters. C. F. Williams. (N. C. Sta. Tech. Bul. 23, pp. 31, pls. 2, figs. 16. June, 1923.)
The inheritance of blotch leaf in maize. R. A. Emerson. (N. Y. Cornell Sta. Mem. 70, pp. 16, pls. 3. June, 1923.)
The inheritance of a lethal pale green seedling character in maize. A. M. Brunson. (N. Y. Cornell Sta. Mem. 72, pp. 22, pl. 1. Jan., 1924.)
Inheritance of size and conformation in sheep. E. G. Ritzman. (N. H. Sta. Tech. Bul. 25, pp. 36, figs. 4. June, 1923.)

FIELD CROPS

Alfalfa. G. R. Quesenberry. (N. Mex. Sta. Bul. 139, pp. 19, figs. 7. May, 1923.)
Alfalfa in Connecticut. D. A. Brown and W. L. Slate, jr. (Conn. Storrs Sta. Bul. 115, pp. 299–323. June, 1923.)
Growing alfalfa in Montana. E. N. Bressman. (Mont. Sta. Circ. 116, pp. 30, figs. 22. Aug., 1923.)
Alfalfa fertilizer experiments. C. E. Craig and W. T. Conway. (N. Mex. Sta. Bul. 137, pp. 22, pl. 1, fig. 1. Mar., 1923.)

Washington barleys. E. G. Schafer, E. F. Gaines, and O. E. Barbee. (Wash. Col. Sta. Bul. 181, pp. 25, figs. 6. Feb., 1924.)

Growing field beans in Montana. C. McKee. (Mont. Sta. Circ. 125, pp. 8. Apr., 1924.)

The clovers and clover seed production in Michigan. J. F. Cox and C. R. Megee. (Mich. Sta. Spec. Bul. 130, pp. 23, figs. 14. Mar., 1924.)

Clover seed from southern Europe fails on Indiana farms. G. I. Christie. (Ind. Sta. Circ. 114, pp. 4, figs. 2. Dec., 1923.)

Growing and using sweet clover in Montana. C. McKee. (Mont. Sta. Circ. 118, pp. 32, figs. 16. Oct., 1923.)

Tifton bur clover. W. J. Davis. (Ga. Coastal Plain Sta. [Tifton, Ga.] Circ. 2, pp. 4, fig. 1. July, 1923.)

Melilotus indica on fall plant sugar cane. W. G. Taggart. (La. Stas. Bul. 189, pp. 11. Aug., 1923.)

Corn breeding. C. W. Lindstrom. (Wis. Sta. Bul. 356, pp. 38 + [1], figs. 10. Aug., 1923.)

Effect of first generation hybrids upon yield of corn. L. R. Waldron. (N. Dak. Sta. Bul. 177, pp. 16, figs. 2. Apr., 1924.)

Varieties of corn for South Dakota. A. N. Hume. (S. Dak. Sta. Bul. 204, pp. 599–611, figs. 8. Aug., 1923.)

Field corn and silage corn for silage. C. C. Hayden and A. E. Perkins. (Ohio Sta. Bul. 369, pp. 259–288. June, 1923.)

Losses and exchanges of material during the storage of corn as silage. A. E. Perkins. (Ohio Sta. Bul. 370, pp. 289–306. June, 1923.)

Ensiling versus drying soft ear corn. J. M. Evvard, A. R. Lamb, and E. J. Maynard. (Iowa Sta. Bul. 216, pp. 401–432, figs. 4. July, 1923.)

Relative water requirement of corn and sorghums. E. C. Miller. (Kans. Sta. Tech. Bul. 12, pp. 34, figs. 5. Oct., 1923.)

The relation of moisture content and certain other factors to the popping of popcorn. F. C. Stewart. (N. Y. State Sta. Bul. 505, pp. 70, pls. 4. Dec., 1923.)

The popping of popcorn. J. D. Luckett. (N. Y. State Sta. Bul. 505, pop. ed., pp. 13, figs. 3. Feb., 1924.)

Popcorn pointers. A. F. Yeager. (N. Dak. Sta. Circ. 24, pp. 8, figs. 3. Apr., 1924.)

Cotton. J. C. Overpeck and W. T. Conway. (N. Mex. Sta. Bul. 141, pp. 17, figs. 3. Jan., 1924.)

Cotton production, factors affecting earliness and yield. C. P. Blackwell and T. S. Buie. (S. C. Sta. Bul. 219, pp. 48, figs. 9. Mar., 1924.)

Cotton experiments, 1923.—Varieties, fertilizers, and weevil control. J. F. O'Kelly and R. Cowart. (Miss. Sta. Bul. 219, pp. 11. Dec., 1923.)

Cotton growing in Illinois. J. A. Evans, J. C. Hackleman, and F. C. Bauer. (Ill. Sta. Circ. 279, pp. 8, figs. 2. Mar., 1924.)

Cotton culture in Tennessee. C. A. Mooers and S. A. Robert. (Tenn. Sta. Bul. 127, pp. 19, figs. 6. Apr., 1923.)

Flaxseed production. T. E. Stoa and A. C. Dillman. (N. Dak. Sta. Bul. 178, pp. 43, figs. 11. Apr., 1924.)

Better flaxseed production. T. E. Stoa. (N. Dak. Sta. Circ. 23, pp. 8, figs. 8. Feb., 1924.)

Emergency hay crops. G. B. Mortimer. (Wis. Sta. Bul. 359, pp. 16, figs. 5. Jan., 1924.)

Studies of various factors influencing the yield and the duration of life of meadow and pasture plants. R. S. Wiggans. (N. Y. Cornell Sta. Bul. 424, pp. 24, figs. 6. Aug., 1923.)

West Virginia pastures. C. E. Stockdale. (W. Va. Sta. Circ. 35, pp. 4. Jan., 1924.)

Washington oats. E. G. Schafer, E. F. Gaines, and O. E. Barbee. (Wash. Col. Sta. Bul. 179, pp. 29, figs. 12. Dec., 1923.)

Seed potato investigations. H. O. Werner and R. F. Howard. (Nebr. Sta. Research Bul. 24, pp. 58, figs. 23. Dec., 1923.)

Certified seed in Irish potato production. A. M. Musser and C. A. Ludwig. (S. C. Sta. Bul. 218, pp. 16. Dec., 1923.)

Studies on certified seed potatoes. B. A. of the potato. W. P. Headden. (Colo. Storrs Sta. Bul. 114, pp. 285–296. May, 1923.)

The effects of nitrates on the composition of the potato. W. P. Headden. (Colo. Sta. Bul. 291, pp. 32. Apr., 1924.)

Ten years of potato spraying in New Jersey. W. H. Martin. (N. J. Stas. Bul. 383, pp. 32. Apr., 1923.)

Irrigation experiments with potatoes. F. S. Harris and D. W. Pittman. (Utah Sta. Bul. 187, pp. 15, figs. 6. Sept., 1923.)

The sorghums in Arizona. G. E. Thompson. (Ariz. Sta. Bul. 98, pp. 41–66, figs. 8. Dec., 1923.)

Soy beans: Their culture and uses. C. F. Noll and R. D. Lewis. (Pa. Sta. Bul. 187, pp. 15, fig. 1. Apr., 1924.)

Soy bean culture. T. K. Wolfe, (Va. Sta. Bul. 235, pp. 32, figs. 15. Mar., 1924.)

Irrigation experiments with sugar beets. F. S. Harris and D. W. Pittman. (Utah Sta. Bul. 186, pp. 19, figs. 10. Sept., 1923.)

Sunflowers under irrigation in Montana. I. J. Jensen. (Mont. Sta. Bul. 162, pp. 19, figs. 11. Dec., 1923.)

Harvesting and storing sweet potatoes. J. C. C. Price. (Ala. Sta. Bul. 220, pp. 14, figs. 6. Nov., 1923.)

The sweet potato in Hawaii. H. L. Chung. (Hawaii Sta. Bul. 50, pp. II+20, pls. 4. Oct., 1923.)

Results of tobacco experiments in Pennsylvania, 1912 to 1922. (Pa. Sta. Bul. 179, pp. 28, figs. 25. June, 1923.)

Bright tobacco culture in Georgia. J. C. Hart. (Ga. Coastal Plain Sta. [Tifton, Ga.] Circ. 3, pp. 8, figs. 7. Jan., 1924.)

Experiments with bright tobacco and other crops grown on bright tobacco farms. T. B. Hutcheson and D. J. Berger. (Va. Sta. Bul. 233, pp. 19, fig. 1. Sept., 1923.)

Turkish tobacco culture, curing, and marketing. W. T. Clarke. (Calif. Sta. Bul. 366, pp. 639–676, figs. 17. June, 1923.)

Winter wheat in North Dakota. L. R. Waldron and T. E. Stoa. (N. Dak. Sta. Bul. 169, pp. 12. Aug., 1923.)

Winter wheat in South Dakota. A. T. Evans and G. Janssen. (S. Dak. Sta. Bul. 200, pp. 487–516, fig. 1. Dec., 1922.)

Some experiments with spring wheat in South Dakota. A. N. Hume and A. T. Evans. (S. Dak. Sta. Bul. 201, pp. 518–560. Feb., 1923.)

Federation wheat. A. E. McClymonds and C. B. Ahlson. (Idaho Sta. Circ. 35, pp. 11, figs. 3. Jan., 1924.)

Michikoff wheat, a hard, red winter wheat for Indiana. A. T. Wiancko. (Ind. Sta. Circ. 112, pp. 4, figs. 2. June, 1923.)

Wheat and flax as combination crops. A. C. Arny. (Minn. Sta. Bul. 206, pp. 12, figs. 3. Mar., 1924.)

Dockage in wheat in North Dakota. Foster County in detail. A. H. Benton. (N. Dak. Sta. Bul. 172, pp. 15, figs. 7. Feb., 1924.)

Seeding small grain in furrows. S. C. Salmon. (Kans. Sta. Tech. Bul. 13, pp. 55, figs. 16. Jan., 1924.)

Fall-sown grain in the coastal plain of Georgia. W. J. Davis. (Ga. Coastal Plain Sta. [Tifton, Ga.], Circ. 1, pp. 4. Oct., 1921.)

Sixteen years' grain production at the North Platte Substation. L. L. Zook and W. W. Burr. (Nebr. Sta. Bul. 193, pp. 52, figs. 6. July, 1923.)

Forage crops for Oregon coast counties. A. E. Engbretson and G. R. Hyslop. (Oreg. Sta. Bul. 203, pp. 32, figs. 5. May, 1924.)

Legumes in relation to soil fertility. M. J. Funchess. (Ala. Sta. Circ. 48, pp. 18, figs. 3. Aug., 1923.)

Inoculation for legumes. W. A. Albrecht. (Mo. Sta. Circ. 121, pp. 12, figs. 5. May, 1924.)

The efficiency of legume inoculation for Arizona soils. R. S. Hawkins. (Ariz. Sta. Tech. Bul. 4, pp. 61–85, figs. 8. May, 1923.)

Dry farming investigations at the Scottsbluff substation. L. L. Zook. (Nebr. Sta. Bul. 192, pp. 23, fig. 1. July, 1923.)

A statistical study of some field plat yields: I, Tobacco investigations at Baldwinsville in cooperation with the Bureau of Plant Industry, United States Department of Agriculture. II, The clover versus timothy experiment on the station farm at Geneva. III, Fertilizer plat experiments on the station farm at Geneva. R. C. Collison and J. D. Harlan. (N. Y. State Sta. Tech. Bul. 94, pp. 64, figs. 5. July, 1923.)

The interpretation of correlation data. A. B. Conner. (Tex. Sta. Bul. 310, pp. 24, figs. 3. Sept., 1923.)

The eradication of bindweed. L. E. Call and R. E. Getty. (Kans. Sta. Circ. 101, pp. 18, figs. 10. Dec., 1923.)

HORTICULTURE

Farm orchards. J. G. Moore. (Wis. Sta. Bul. 363, pp. 35, figs. 25. Apr., 1924.)

New or noteworthy fruits, VII. U. P. Hedrick. (N. Y. State Sta. Bul. 514, pp. 10, pls. 6. Feb., 1924.)

Picking, handling, and exhibiting fruit. T. J. Talbert and A. M. Burroughs. (Mo. Sta. Circ. 113, pp. 7, fig. 1. Aug., 1923.)

Commercial fertilizers in New York orchards. R. C. Collison and J. D. Harlan. Summarized by J. D. Luckett. (N. Y. State Sta. Bul. 503, pop. ed., pp. 4. July, 1923.)

Orchard cultural practices. H. Thornber. (Mont. Sta. Bul. 156, pp. 19, figs. 5. Mar., 1923.)

Self-sterility and self-fertility of fruit varieties grown in New York. R. Wellington. (N. Y. State Sta. Circ. 71, pp. 6. Dec., 1923.)

Propagation and top-working of orchard fruits. R. P. Armstrong and F. J. Rimoldi. (N. J. Stas. Circ. 158, pp. 31, figs. 17. Mar., 1924.)

Pruning fruit plants. R. J. Barnett. (Kans. Sta. Circ. 102, pp. 24, figs. 12. Feb., 1924.)

A study of deciduous fruit tree root stocks with special reference to their identification. M. J. Heppner. (Calif. Sta. Tech. Paper 6, pp. 36, pls. 6. June, 1923.)

Studies of fruit seed storage and germination. H. B. Tukey. (N. Y. State Sta. Bul. 509, pp. 19. Jan., 1924.)

The cause and permanence of size differences in apple trees. K. Sax and J. W. Gowen. (Me. Sta. Bul. 310, pp. 8, pl. 1, fig. 1. Feb., 1923.)

Hardy varieties of apples for northeastern Colorado. E. P. Sandsten. (Colo. Sta. Bul. 292, pp. 8. May, 1924.)

Blooming periods of apples. C. S. Crandall. (Ill. Sta. Bul. 251, pp. 111–145. May, 1924.)

Fertilizing apple orchards. History of station experiment. U. P. Hedrick. (N. Y. State Sta. Circ. 66, pp. 8, fig. 1. Mar., 1923.)

Nitrogen-carrying fertilizers and the bearing habits of mature apple trees. F. C. Bradford. (Mich. Sta. Spec. Bul. 127, pp. 32, figs. 7. Jan., 1924.)

Effect of shading and ringing upon the chemical composition of apple and peach trees. H. R. Kraybill. (N. H. Sta. Tech. Bul. 23, pp. 27. June, 1923.)

A study of growth in summer shoots of the apple, with special consideration of the rôle of carbohydrates and nitrogen. E. M. Harvey. (Oreg. Sta. Bul. 200, pp. 51, figs. 27. Dec., 1923.)

Pruning young apple trees. F. P. Cullinan and C. E. Baker. (Ind. Sta. Bul. 274, pp. 40, figs. 13. May, 1923.)

How and when to prune apple trees. G. H. Howe. Summarized by J. D. Luckett. (N. Y. State Sta. Bul. 500, pop. ed., pp. 7, figs. 3. July, 1923.)

Pruning apple and pear trees. T. J. Talbert. (Mo. Sta. Circ. 120, pp. 16, figs. 13. May, 1924.)

Spraying and dusting experiments with apples in 1923. P. J. Parrott, F. C. Stewart, and H. Glasgow. (N. Y. State Sta. Circ. 70, pp. 9. Dec., 1923.)

The apple tree crotch. L. H. MacDaniels. (N. Y. Cornell Sta. Bul. 419, pp. 22, figs. 16. May, 1923.)

Twenty years' profits from an apple orchard. U. P. Hedrick. (N. Y. State Sta. Bul. 510, pp. 14, figs. 2. Jan., 1924.)

Avocado culture in California: Part I, History, culture, varieties, and marketing. K. Ryerson. Part II, Composition and food value. M. E. Jaffa and H. Goss. (Calif. Sta. Bul. 365, pp. 571–638, figs. 19. June, 1923.)

Analyzing the citrus orchard by means of simple tree records. R. W. Hodgson. (Calif. Sta. Circ. 266, pp. 20, figs. 11. June, 1923.)

A survey of orchard practices in the citrus industry of Southern California. R. S. Vaile. (Calif. Sta. Bul. 374, pp. 40, figs. 4. Jan., 1924.)

The pruning of citrus trees in California. R. W. Hodgson. (Calif. Sta. Bul. 363, pp. 487–532, figs. 20. May, 1923.)

Studies on the effects of sodium, potassium and calcium on young orange trees. H. S. Reed and A. R. C. Haas. (Calif. Sta. Tech. Paper 11, pp. 32, pls. 5. Oct., 1923.)

Saving the gophered citrus tree. R. W. Hodgson. (Calif. Sta. Circ. 273, pp. 19, figs. 10. Dec., 1923.)

The Satsuma orange in south Mississippi. E. B. Ferris and F. B. Richardson. (Miss. Sta. Bul. 217, pp. 28, figs. 5. Apr., 1923.)

The acid lime fruit in Hawaii. W. T. Pope. (Hawaii Sta. Bul. 49, pp. 20, pls. 6. July, 1923.)

The red and white currants. P. Thayer. (Ohio Sta. Bul. 371, pp. 305–394, pls. 14, figs. 8. June, 1923.)

Peach culture in Missouri. H. D. Hooker, jr. (Mo. Sta. Bul. 207, pp. 14, figs. 2. Dec., 1923.)
An analysis of the peach variety question in Michigan. S. Johnston. (Mich. Sta. Spec. Bul. 126, pp. 48, figs. 12. Jan. 1924.)
Fertilizing peach trees. H. L. Crane. (W. Va. Sta. Circ. 37, pp. 4. Apr., 1924.)
Experiments in fertilizing peach trees. H. L. Crane. (W. Va. Sta. Bul. 183, pp. 72, figs. 24. Mar., 1924.)
Moisture relations of peach buds during winter and spring. E. S. Johnston. (Md. Sta. Bul. 255, pp. 57–88, figs. 9. June, 1923.)
The pineapple pear. J. G. Woodroof. (Ga. Sta. Bul. 142, pp. 77–105, figs. 8. Oct., 1923.)
Pear pollination. W. P. Tufts and G. L. Philp. (Calif. Sta. Bul. 373, pp. 36, figs. 11. Dec., 1923.)
Establishing a commercial vineyard in Arizona. F. J. Crider. (Ariz. Sta. Bul. 96, pp. 46, figs. 30. June, 1923.)
Grape growing in Missouri. H. G. Swartwout. (Mo. Sta. Bul. 208, pp. 36, figs. 19. Jan., 1924.)
The cane fruit industry in Oregon. H. Hartman. (Oreg. Sta. Circ. 48, pp. 28, figs. 10. July, 1923.)
The strawberry. P. Thayer. (Ohio Sta. Bul. 364, pp. 61–98, figs. 31. June, 1923.)
Sterility of strawberries. Strawberry breeding. M. B. Cummings and E. W. Jenkins. (Vt. Sta. Bul. 232, pp. 61, pls. 2, figs. 6. May, 1923.)
Production of improved hardy strawberries for Alaska. C. C. Georgeson. (Alaska Stas. Bul. 4, pp. [2] + 13, pls. 10. Oct., 1923.)
Studies in the nutrition of the strawberry. V. R. Gardner. (Mo. Sta. Research Bul. 57, pp. 31. Mar., 1923.)
Strawberry culture in Wisconsin. J. G. Moore. (Wis. Sta. Bul. 360, pp. 24, figs. 10. Feb., 1924.)
The relation of humidity to the texture, weight and volume of filberts. H. Hartman. (Oreg. Sta. Bul. 202, pp. 22, figs. 7. Apr., 1924.)
Top-working pecan trees. G. H. Blackmon. (Fla. Sta. Bul. 170, pp. 165–188, figs. 21. May, 1924.)
Methods of harvesting and irrigation in relation to moldy walnuts. L. D. Batchelor. (Calif. Sta. Bul. 367, pp. 675–696, pls. 2. June, 1923.)
Sun-drying and dehydration of walnuts. L. D. Batchelor, A. W. Christie, E. H. Guthier, and R. G. LaRue. (Calif. Sta. Bul. 376, pp. 26, figs. 9. Mar., 1924.)
Preliminary report on experiments with the tung oil tree in Florida. W. Newell. (Fla. Sta. Bul. 171, pp. 189–234, figs. 20. May, 1924.)
House plants and their care. W. B. Balch. (Kans. Sta. Circ. 100, pp. 16, figs. 6. Oct., 1923.)
Perennial flowers for North Dakota homes. A. F. Yeager and F. M. Heath. (N. Dak. Sta. Bul. 170, pp. 56, figs. 27. Dec., 1923.)
Marketable California decorative greens. C. L. Flint. (Calif. Sta. Circ. 275, pp. 15, figs. 6. Feb., 1924.)
Dahlias in the garden. C. H. Conners. (N. J. Stas. Circ. 154, pp. 24, figs. 12. June, 1923.)
Some studies in the production of double blooms of stocks (*Matthiola incana annua*). T. H. White. (Md. Sta. Bul. 259, pp. 85–104, figs. 3. Nov., 1923.)
Beautifying the home grounds, for the smaller type. E. M. Lowry. (Colo. Sta. Bul. 290, pp. 20, figs. 15. Jan., 1924.)
A plan for the farm garden. (Ill. Sta. Circ. 278, pp. 8, figs. 3. Feb., 1924.)
The quality of packet vegetable seed on sale in New York. M. T. Munn and E. F. Hopkins. (N. Y. State Sta. Bul. 507, pp. 23. Jan., 1924.)
On the amount of stable manure necessary for vegetable growing. B. L. Hartwell and F. K. Crandall. (R. I. Sta. Bul. 195, pp. 16. Aug., 1923.)
Bean growing in Michigan. J. F. Cox and H. R. Pettigrove. (Mich. Sta. Spec. Bul. 129, pp. 21, figs. 17. Apr., 1924.)
Cabbage production in California. H. A. Jones. (Calif. Sta. Circ. 262, pp. 22, figs. 9. May, 1923.)
Lettuce growing in New Jersey. H. F. Huber. (N. J. Stas. Circ. 155, pp. 24, figs. 16. Mar., 1924.)
Onion growing in North Dakota. A. F. Yeager. (N. Dak. Sta. Bul. 173, pp. 12, figs. 7. Feb., 1924.)
Changes in quality and chemical composition of parsnips under various storage conditions. V. R. Boswell. (Md. Sta. Bul. 258, pp. 59–86, figs. 8. Oct., 1923.)
Spinach studies in Passaic County, and cultural notes. L. G. Schermerhorn. (N. J. Stas. Bul. 385, pp. 11, figs. 6. June, 1923.)
Sweet corn in the higher altitudes. H. Thornber. (Mont. Sta. Bul. 157, pp. 19, figs. 3. Mar., 1923.)
Forecasting the date and duration of the best canning stage for sweet corn. C. O. Appleman. (Md. Sta. Bul. 254, pp. 47–56, fig. 1. May, 1923.)
Tomato production in California. J. T. Rosa, jr. (Calif. Sta. Circ. 263, pp. 19, figs. 6. May, 1923.)
Tomato growing in Michigan. E. P. Lewis. (Mich. Sta. Spec. Bul. 131, pp. 14, figs. 11. Mar., 1924.)
Tomato culture in Missouri. J. T Quinn. (Mo. Sta. Bul. 212, pp. 16, figs. 5. May, 1924.)
Economic results in the pollination of greenhouse tomatoes. A. G. B. Bouquet. (Oreg. Sta. Circ. 55, pp. 16, figs. 4. Jan., 1924.)
Watermelons. H. P. Stuckey. (Ga. Sta. Bul. 143, pp. 109–131, figs. 4. Feb., 1924.)
Orchard spraying. L. M. Peairs and E. C. Sherwood. (W. Va. Sta. Circ. 36, pp. 20. Mar., 1924.)
Directions for spraying fruits in Illinois. (Ill. Sta. Circ. 277, pp. 24, figs. 4. Feb., 1924.)
Spray calendar for apples and quinces. (N. J. Stas. Circ. 162, pp. 4, fig. 1. Feb., 1924.)
Spray calendar for peaches. (N. J. Stas. Circ. 163, pp. 4, figs. 3. Feb., 1924.)
Spray calendar for pears. (N. J. Stas. Circ. 164, pp 4, figs. 3. Feb., 1924.)
Spray calendars for plums and cherries. (N. J. Stas. Circ. 165, pp. 4, fig. 1. Feb., 1924.)
Spray calendar for grapes. (N. J. Stas. Circ. 166, pp. 4, fig. 1. Feb., 1924.)
The preparation of spray materials. R. H. Robinson. (Oreg. Sta. Bul. 201, pp. 15, fig. 1. Jan., 1924.)
A new method of making engine oil emulsions. A. M. Burroughs. (Mo. Sta. Bul. 205, pp. 8, figs. 4. Aug., 1923.)
Greenhouse soil sterilization. H. D. Brown, I. L. Baldwin, and S. D. Conner. (Ind. Sta. Bul. 266, pp. 27, figs. 11. Dec., 1922.)

FORESTRY

Better forests for Connecticut. H. W. Hicock. (Conn. State Sta. Bul. 253, pp. 129–140, figs. 5. Jan., 1924.)

Improvement of the farm woodlot. A. K. Chittenden. (Mich. Sta. Spec. Bul. 122, pp. 22, figs. 7. Sept., 1923.)

Second growth hardwood forests in Michigan. P. L. Buttrick. (Mich. Sta. Spec. Bul. 123, pp. 19, figs. 5. Sept., 1923.)

Preliminary yield tables for second growth redwood. D. Bruce. (Calif. Sta. Bul. 361, pp. 425-467, figs. 5. May, 1923.)

Studies in tolerance of New England forest trees.—IV, Minimum light requirement referred to a definite standard. G. P. Burns. (Vt. Sta. Bul. 235, pp. 32, pls. 4, figs. 14. July, 1923.)

The relative cost of yarding small and large timber. D. Bruce. (Calif. Sta. Bul. 371, pp. 36, figs. 4. Oct., 1923.)

PLANT DISEASES

Plant disease and pest control. W. T. Horne, O. E. Essig, and W. B. Herms. (Calif. Sta. Circ. 265, pp. 104. June, 1923.)

Report on resistant plants for root-knot nematode control. J. A. McClintock. (Ga. Sta. Circ. 77, pp. 4a. Aug., 1923.)

Spraying for control of disease and insects of the apple. R. A. Jehle and E. N. Cory. (Md. Sta. Bul. 262, pp. 155–168. Mar., 1924.)

Apple blotch. M. W. Gardner, L. Greene, and C. E. Baker. (Ind. Sta. Bul. 267, pp. 32, figs. 12. Jan., 1923.)

A study of the darkening of apple tissue. E. L. Overholser and W. V. Cruess. (Calif. Sta. Tech. Paper 7, pp. 40. June, 1923.)

Factors influencing the development of internal browning of the yellow Newtown apple. E. L. Overholser, A. J. Winkler, and H. E. Jacob. (Calif. Sta. Bul. 370, pp. 40, pl. 1, figs. 3. Sept., 1923.)

Crown-gall of apple and peach, with notes on the biology of *Bacterium tumefaciens*. D. Reddick and V. B. Stewart. (N. Y. Cornell Sta. Mem. 73, pp. 19, pls. 2, figs. 4. Mar., 1924.)

Apple scab and its control in Virginia. F. J. Schneiderhan and F. D. Fromme. (Va. Sta. Bul. 236, pp. 29, figs. 7. Mar., 1924.)

Combating apple scab.—Spraying and dusting experiments in 1923, with summary of three years' results. W. L. Doran and A. V. Osmun. (Mass. Sta. Bul. 219, pp. 17. Jan., 1924.)

Citrus blast and black pit. H. S. Fawcett, W. T. Horne, and A. F. Camp. (Calif. Sta. Tech. Paper 5, pp. 36, pls. 6. May, 1923.)

Gum diseases of citrus trees in California. H. S. Fawcett. (Calif. Sta. Bul. 360, pp. 369–423, figs. 15. Apr., 1923.)

Mosaic and other systemic diseases of brambles in Oregon. S. M. Zeller. (Oreg. Sta. Circ. 49, pp. 15, figs. 9. July, 1923.)

Anthracnose of cane fruits and its control on black raspberries in Wisconsin. L. K. Jones. (Wis. Sta. Research Bul. 59, pp. 26, pls. 8, figs. 4. May, 1924.)

Brown rot and related diseases of stone fruits in Oregon. H. P. Barss. (Oreg. Sta. Circ. 53, pp. 18, figs. 10. Dec., 1923.)

Fruit-rotting sclerotinias.—I, Apothecia of the brown-rot fungus. J. B. S. Norton, W. N. Ezekiel, and R. A. Jehle. (Md. Sta. Bul. 256, pp. 36, figs. 18. Aug., 1923.)

A study of the damping off disease of coniferous seedlings. T. S. Hansen et al. (Minn. Sta. Tech. Bul. 15, pp. 35, figs. 20. Apr., 1923.)

Truck crop investigations.—Hot water treatment for nematode control. H. H. Zimmerly and H. Spencer. (Va. Truck Sta. Bul. 43, pp. 265–278, figs. 6. Apr., 1923.)

Cabbage seed bed diseases and Delphinium root rots, their relation to certain methods of cabbage maggot control. W. O. Gloyer and H. Glasgow. (N. Y. State Sta. Bul. 513, pp. 38, pls. 6. Feb., 1924.)

Investigations of cauliflower diseases on Long Island. E. E. Clayton. (N. Y. State Sta. Bul. 506, pp. 15, pls. 8, fig. 1. Jan., 1924.)

Studies in Michigan celery diseases.—II, A study of the early blight fungus, *Cercospora apii* Fres. L. J. Klotz. (Mich. Sta. Tech. Bul. 63, pp. 43, figs. 10. Nov., 1923.)

The influence of hydrogen-ion concentration on the growth of *Fusarium lycopersici* and on tomato wilt. I. T. Scott. (Mo. Sta. Research Bul. 64, pp. 32, figs. 10. Jan., 1924.)

Factors influencing the pathogenicity of *Helminthosporium sativum*. L. Dosdall. (Minn. Sta. Tech. Bul. 17, pp. 47, pls. 6, figs. 7. July, 1923.)

Dry rot of corn. L. W. Durrell. (Iowa Sta. Research Bul. 77, pp. 345–376, pls. 3, figs. 13. July, 1923.)

Corn root rot. B. B. Branstetter. (Mo. Sta. Circ. 117, pp. 8, figs. 4. Mar., 1924.)

Texas root rot of cotton and methods of its control. J. J. Taubenhaus and D. T. Killough. (Tex. Sta. Bul. 307, pp. 98, figs. 15. Apr., 1923.)

Potato diseases and insects. G. F. Weber. (Fla. Sta. Bul. 169, pp. 101–164, figs. 55. Dec., 1923.)

Potato disease control in Kansas. E. A. Stokdyk and L. E. Melchers. (Kans. Sta. Bul. 231, pp. 45, figs. 16. Mar., 1924.)

Michigan potato diseases. G. H. Coons and J. E. Kotilla. (Mich. Sta. Spec. Bul. 125, pp. 55, figs. 47. Dec., 1923.)

Effect of environment on potato degeneration diseases. R. W. Goss. (Nebr. Sta. Research Bul. 26, pp. 40, figs. 3. Mar., 1924.)

Potato spindle-tuber. D. Folsom. (Me. Sta. Bul. 312, pp. 19–44, pls. 4, figs. 2. Aug., 1923.)

Late blight of potatoes and the weather. W. H. Martin. (N. J. Stas. Bul. 384, pp. 23, figs. 2. Apr., 1923.)

Potato hopperburn (tipburn) control with Bordeaux mixture. T. H. Parks and E. E. Clayton. (Ohio Sta. Bul. 368, pp. 241–258, figs. 7. June, 1923.)

Sunflower rust. D. L. Bailey. (Minn. Sta. Tech. Bul. 16, pp. 31, pls. 3. Aug., 1923.)

Recommendations for the control of wildfire (revised). (Conn. State Sta. Tobacco Substation [Windsor, Conn.] Bul. 4, pp. 2. Mar., 1924.)

Wheat scab in Minnesota. J. MacInnes and R. Fogelman. (Minn. Sta. Tech. Bul. 18, pp. 34, pls. 9, figs. 4. Aug., 1923.)

Fighting black stem rust of grain by eradicating the barberry. N. F. Thompson and J. G. Dickson. (Wis. Sta. Bul. 357, pp. 28, figs. 16. May, 1923.)

A study of the environmental conditions influencing the development of stem rust in the absence of an alternate host.—II, Infection studies with *Puccinia graminis tritici*, form III and form IX. G. L. Peltier. (Nebr. Sta. Research Bul. 25, pp. 52, pls. 12. Dec., 1923.)

Flag smut of wheat with special reference to varietal resistance. W. H. Tisdale, G. H. Dungan, and C. E. Leighty. (Ill. Sta. Bul. 242, Abs., pp. 4, fig. 1. May, 1923.)
Fungicidal dusts for the control of bunt. W. W. Mackie and F. N. Briggs. (Calif. Sta. Bul. 364, pp. 533–572, pls. 3, figs. 12. May, 1923.)

ENTOMOLOGY AND ZOOLOGY

Common pests of field and garden crops. R. H. Pettit. (Mich. Sta. Spec. Bul. 132, pp. 60, figs. 41. Mar., 1924.)
Truck crop insect pests in the Virgin Islands and methods of combating them. C. E. Wilson. (V. I. Sta. Bul. 4, pp. 35, figs. 24. June, 1923.)
The fruit tree leaf-roller in the Bitter Root Valley. W. S. Regan. (Mont. Sta. Bul. 154, pp. 56, figs. 8. Feb., 1923.)
The apple flea-weevil. J. S. Houser. (Ohio Sta. Bul. 372, pp. 393–434, figs. 16. June, 1923.)
The peach tree borer in New Jersey (with notes on similar pests). A. Peterson. (N. J. Stas. Bul. 391, pp. 143, figs. 26, Aug., 1923.)
Controlling peach tree borers with paradichlorobenzene. O. C. McBride. (Mo. Sta. Circ. 112, pp. 4, figs. 2. June, 1923.)
Control of the western peach and prune root borer. D. C. Mote. (Oreg. Sta. Circ. 50, pp. 4, figs. 3. Aug., 1923.)
Tentative plan for combating oriental peach moth. T. J. Headlee. (N. J. Stas. Circ. 167, pp. 4, figs. 3. Mar., 1924.)
The present status of the oriental fruit moth in northern Virginia, with report of recent orchard spraying experiments on its control. L. A. Stearns. (Va. Sta. Bul. 234, pp. 28, figs. 10. Feb., 1924.)
Spraying and dusting for the control of pear psylla. F. Z. Hartzell. (N. Y. State Sta. Circ. 72, pp. 14. Jan., 1924.)
Insect pests and diseases of bramble fruits. A. L. Lovett and H. P. Barss. (Oreg. Sta. Circ. 45, pp. 16, figs. 8. June, 1923.)
The raspberry fruit worm. B. H. Walden. (Conn. State Sta. Bul. 251, pp. 89–99, pls. 4, fig. 1. Dec., 1923.)
I, The strawberry weevil. II, A false wireworm on strawberry. W. J. Baerg. (Ark. Sta. Bul. 185, pp. 33, pls. 3, figs. 3. May, 1923.)
Alfalfa weevil and its control in Idaho. C. Wakeland. (Idaho Sta. Circ. 34, pp. 11. Jan., 1924.)
Life history and control of the Mexican bean beetle. F. L. Thomas. (Ala. Sta. Bul. 221, pp. 99, figs. 25. Jan., 1924.)
The Mexican bean beetle in Kentucky. H. Garman. (Ky. Sta. Circ. 31, pp. 16, figs. 8. Dec., 1923.)
The blueberry maggot in Washington County. E. M. Patch and W. C. Woods. (Me. Sta. Bul. 308, pp. 77–92, pl. 1. Nov., 1922.)
Surface treatments for the cabbage maggot. W. C. O'Kane, C. R. Cleveland, and C. H. Hadley. (N. H. Sta. Tech. Bul. 24, pp. 42. June, 1923.)
Three little-known clover insects. J. D. Detwiler. (N. Y. Cornell Sta. Bul. 420, pp. 28, figs. 24. May, 1923.)
Begin to fight the corn borer now. W. P. Flint, J. C. Hackleman, and F. C. Bauer. (Ill. Sta. Circ. 274, pp. 8, figs. 6. Nov., 1923.)
Boll weevil investigations in 1923. (S. C. Sta. Circ. 31, pp. 29, figs. 4. Jan., 1924.)
The boll weevil problem in Arkansas. D. Isely and W. J. Baerg. (Ark. Sta. Bul. 190, pp. 29, figs. 8. Jan., 1924.)
Methods of boll weevil control. R. P. Bledsoe. (Ga. Sta. Circ. 78, pp. 5a–12a. Feb., 1924.)
A progress report of boll weevil poisoning work at the Holly Springs Branch Experiment Station. C. T. Ames. (Miss. Sta. Circ. 51, pp. 11. Dec., 1923.)
Nicotin dust kills cucumber beetles. J. E. Dudley, jr., H. F. Wilson, and W. D. Mecum. (Wis. Sta. Bul. 355, pp. 10, figs. 4. June, 1923.)
Bionomics and control of the potato leafhopper, *Empoasca mali* Le Baron, F. A. Fenton and A. Hartzell. (Iowa Sta. Research Bul. 78, pp. 377–440, pl. 1, figs. 22. July, 1923.)
The insects of the soy bean in Ohio. W. V. Balduf. (Ohio Sta. Bul. 366, pp. 145–181, figs. 9. June, 1923.)
Control of the squash vine borer in Massachusetts. H. N. Worthley. (Mass. Sta. Bul. 218, pp. 69–80, pls. 2, figs. 2. Oct., 1923.)
The squash lady-bird beetle. G. W. Underhill. (Va. Sta. Bul. 232, pp. 24, figs. 8. July, 1923.)
The sweet potato weevil. H. J. Reinhard. (Tex. Sta. Bul. 308, pp. 90, figs. 5. Apr., 1923.)
The sweet potato weevil in Louisiana and its control. C. E. Smith. (La. Stas. Bul. 188, pp. 24, figs. 5. Aug., 1923.)
Control of ant invasions. W. E. Britton. (Conn. State Sta. Bul. of Immed. Inform. 17, pp. 6. July, 1922.)
The control of plant lice on vegetables. J. L. Horsfall. (Pa. Sta. Bul. 186, pp. 16, figs. 6. Mar., 1924.)
The summer food plants of the green apple aphid. E. M. Patch. (Me. Sta. Bul. 313, pp. 43–68, figs. 8. Oct., 1923.)
The effects of feeding punctures of aphids on certain plant tissues. J. L. Horsfall. (Pa. Sta. Bul. 182, pp. 22, figs. 7. Nov., 1923.)
Cyanide for bed bugs. A. L. Strand. (Mont. Sta. Circ. 123, pp. 7, figs. 3. Feb., 1924.)
The normal and pathological history of the ventriculus of the honey bee, with special reference to infection with *Nosema apis*. M. Hertig. (Minn. Sta. Tech. Bul. 13, pp. [2] + 109–140, pls. 3. July, 1923.)
Bee diseases in Montana. O. A. Sippel. (Mont. Sta. Circ. 120, pp. 14, figs. 5. Dec., 1923.)
Calcium cyanide for chinchbug control. W. P. Flint and W. V. Balduf. (Ill. Sta. Bul. 249, pp. 71–84, figs. 6. May, 1924.)
Life history of the codling moth in Arkansas, with special reference to factors limiting abundance. D. Isely and A. J. Akerman. (Ark. Sta. Bul. 189, pp. 57, figs. 8. Dec., 1923.)
The European red mite. P. Garman. (Conn. State Sta. Bul. 252, pp. 101–125, pls. 4, figs. 4. Dec., 1923.)
Grasshopper control in Colorado. C. L. Corkins. (Colo. Sta. Bul. 287, pp. 19, figs. 17. June, 1923.)
The gipsy moth quarantine. D. M. Rogers and W. E. Britton. (Conn. State Sta. Bul. of Immed. Inform. 18, pp. 4, fig. 1. Aug., 1922.)
Hessian fly control in Iowa. C. J. Drake, F. A. Fenton, and F. D. Butcher. (Iowa Sta. Circ. 86, pp. 11, figs. 5. July, 1923.)
The Hessian fly in Kansas. J. W. McCulloch. (Kans. Sta. Tech. Bul. 11, pp. 96, figs. 29. July, 1923.)

Spray to prevent the attack of Japanese beetle. (N. J. Stas. Circ. 168, pp. 4, figs. 2. Mar., 1924.)

Fumigation of potting soil with carbon bisulfide for the control of the Japanese beetle (*Popillia japonica,* Newm.). W. E. Fleming. (N. J. Stas. Bul. 380, pp. 45, figs. 7. Jan., 1923.)

Observations on the relations between atmospheric conditions and the behavior of mosquitoes. W. Rudolfs. (N. J. Stas. Bul. 388, pp. 32, figs. 6. Sept., 1923.)

Scale insects of Missouri. A. H. Hollinger. (Mo. Sta. Research Bul. 58, pp. 71, pls. 7. Apr., 1923.)

Spraying for oyster-shell scale. R. A. Cooley, J. R. Parker, and W. S. Regan. (Mont. Sta. Circ. 124, pp. 15, figs. 4. Mar., 1924.)

Sprays for San José scale and leaf-roller. A. L. Melander. (Wash. Col. Sta. Pop. Bul. 126, pp. 14, fig. 1. Feb., 1924.)

The pickle worm and its control. K. C Sullivan. (Mo. Sta. Circ. 122, pp. 4, figs. 2. June, 1924.)

The plains false wireworm and its control. M. H. Swenk. (Nebr. Sta. Circ. 20, pp. 11, figs. 3. July, 1923.)

Life history studies of the *Mysus persicae* Sulzer. J. L. Horsfall. (Pa. Sta. Bul. 185, pp. 16, figs. 3. Feb., 1924.)

Studies of the physical ecology of the Noctuidae. W. C. Cook. (Minn. Sta. Tech. Bul. 12, pp. 38, figs. 5. Mar., 1923.)

Observations on the life history of *Taphrocerus gracilis* (Say) (Beetle family Buprestidae). R. N. Chapman. (N. Y. Cornell Sta. Mem. 67, pp. 13, figs. 10. May, 1923.)

Synopsis and catalog of the Thysanoptera of North America, with a translation of Karny's Keys to the Genera of Thysanoptera and a bibliography of recent publications. J. R. Watson. (Fla. Sta. Bul. 168, pp. 100. Dec., 1923.)

The control of truck crop pests by dusting. E. N. Cory and S. F. Potts. (Md. Sta. Bul. 261, pp. 119–157, figs. 17. Feb., 1924.)

Some principles which underlie the making and use of nicotine dust. T. J. Headlee and W. Rudolfs. (N. J. Stas. Bul. 381, pp. 47, figs. 18. Jan., 1923.)

Para-dichlorobenzene (p-c-benzen) for controlling the peach-tree borer. A. Peterson. (N. J. Stas. Circ. 156 (revision of Circ. 126), pp. 12, figs. 8. Sept., 1923.)

The common garden mole in Iowa. E. E. Dunnam. (Iowa Sta. Circ. 88, pp. 4, figs. 5. Jan., 1924.)

ANIMAL PRODUCTION

ANIMAL NUTRITION AND FEEDING STUFFS

Normal growth of domestic animals. C. R. Moulton et al. (Mo. Sta. Research Bul. 62, pp. 58, figs. 54. Nov., 1923.)

Digestion experiments with cattle feeds. J. B. Lindsey, C. L. Beals, P. H. Smith, and J. G. Archibald. (Mass. Sta. Bul. 216, pp. 52–62. June, 1923.)

Digestive coefficients of poultry feeds and rapidity of digestion and fate of grit in the fowl. B. F. Kaupp and J. E. Ivey. (N. C. Sta. Tech. Bul. 22, pp. 143, figs. 13. June, 1923.)

Digestion experiments with oat by-products and other feeds. G. S. Fraps. (Tex. Sta. Bul. 315, pp. 12, fig. 1. Feb., 1924.)

Studies in animal nutrition.—IV, The nitrogen, ash and phosphorus distribution in beef flesh as affected by age and condition. W. S. Ritchie, C. R. Moulton, P. F. Trowbridge, and L. D. Haigh. (Mo. Sta. Research Bul. 59, pp. 78. May, 1923.)

Studies in animal nutrition.—V, Changes in the composition of the mature dairy cow while fattening. C. R. Moulton, P. F. Trowbridge, and L. D. Haigh. (Mo. Sta. Research Bul. 61, pp. 20. Oct., 1923.)

Vitamins in livestock feeding. H. H. Mitchell and M. H. Keith. Ill. Sta. Circ. 282, pp. 20, figs. 5. June, 1924.)

Silage feeding investigations, 1922–23. C. W. McCampbell and W. R. Horlacher. (Kans. Sta. Circ. 105, pp. 10, figs. 2. Mar., 1924.)

Silage investigations.—Loss of nutrients in the silo and during the field curing of corn. A. C. Ragsdale and C. W. Turner. (Mo. Sta. Research Bul. 65, pp. 10. Feb., 1924.)

The feeding of mineral supplements to livestock. H. H. Mitchell. (Ill. Sta. Circ. 281, pp. 4. May, 1924.)

Calcium metabolism in the laying hen. G. D. Buckner, J. H. Martin, and A. M. Peter. (Ky. Sta. Bul. 250, pp. 329–367. Oct., 1923.)

The microscopic identification and determination of the specific ingredients in stock feeds. O. B. Winter. (Mich. Sta. Spec. Bul. 120, pp. 31, figs. 9. Sept., 1923.)

HORSES

The improvement in the horse industry in Kansas since 1910. (Kans. Sta. Insp. Circ. 15, pp. 3. Dec., 1921.

Soy beans for horses and mules. C. W. Crawford and J. L. Edmonds. (Ill. Sta. Circ. 276, pp. 8, figs. 3. Jan., 1924.)

BEEF CATTLE

Las vaquerías en Puerto Rico. D. W. May. (P. R. Sta. Bul. 29, Span. ed., pp. 16, pls. 4. Jan., 1924.)

Cattle feeding investigations, 1921–22. C. W. McCampbell, H. B. Winchester, and H. W. Marston. (Kans. Sta. Circ. 97, pp. 8, fig. 1. Sept., 1923.)

Preliminary reports of experiments with feeding steers, using cottonseed meal and molasses. E. Barnett and C. J. Godell. (Miss. Sta. Circ. 48, pp. 12, fig. 1. April, 1923.)

Steer feeding experiments, 1922–1923. C. W. Hickman and E. F. Rinehart. (Idaho Sta. Circ. 31 [32], pp. 4. Sept., 1923.)

Steer feeding experiments at the Pennsylvania State College. W. H. Tomhave and F. L. Bentley. (Pa. Sta. Bul. 183, pp. 16, figs. 7. Dec., 1923.)

I, Fattening steers on cottonseed meal and hulls, with and without corn. II, The influence of age on fattening steers. J. M. Jones, J. L. Lush, and J. H. Jones. (Tex. Sta. Bul. 309, pp. 31. June, 1923.)

Wintering range calves. (Wyo. Sta. Bul. 134, pp. 16, fig. 1. May, 1923.)

Feeding cottonseed meal to steers on grass. E. Barnett and C. J. Goodell. (Miss. Sta. Circ. 50, pp. 3. June, 1923.)

The utilization of feed by range steers of different ages. M. G. Snell. (N. Mex. Sta. Bul. 140, pop. ed., pp. 7. Dec., 1923.)

Cattle feeding investigations.—Finishing baby beef. W. L. Blizzard. (Okla. Sta. Bul. 147, pp. 8.)

SHEEP

A comparison of types of lambs and systems of production. J. W. Hammond. (Ohio Sta. Bul. 367, pp. 183–239, figs. 9. June, 1923.)

Sheep feeding.—Fattening western lambs, XII, 1922–1923. J. H. Skinner and F. G. King. (Ind. Sta. Bul. 273, pp. 13, fig. 1. June, 1923.)
Sheep feeding investigations.—Comparative rations for fattening wether lambs. A. E. Darlow. (Okla. Sta. Bul. 146, pp. 7.)
Lamb feeding experiments. J. T. Lanton and M. G. Snell. (N. Mex. Sta. Bul. 138, pp. 12. Apr., 1923.)
Lamb feeding experiments in western Nebraska. J. A. Holden. (Nebr. Sta. Bul. 194, pp. 35, fig. 1. Aug., 1923.)
Winter lamb feeding, 1919–20, 1920–21, 1921–22. W. H. Savin. (Nebr. Sta. Bul. 197, pp. 23, fig. 1. Oct., 1923.)
Fattening lambs on alfalfa. E. L. Potter and H. K. Dean. (Oreg. Sta. Bul. 198, pp. 16, figs. 4. Aug., 1923.)
Corn substitutes for fattening lambs. J. M. Evvard, R. Dunn, and C. C. Culbertson. (Iowa Sta. Bul. 210, pp. 205–229, figs. 11. Mar., 1923.)
Grain sorghums versus corn for fattening lambs.—Third experiment. J. M. Jones and R. E. Dickson. (Tex. Sta. Bul. 306, pp. 32. Feb., 1923.)
Cane and beet molasses for fattening lambs. J. M. Evvard, C. C. Culbertson, and Q. W. Wallace. (Iowa Sta. Bul. 215, pp. 370–400, figs. 3. Apr., 1923.)
The influence of individuality, age, and season upon the weights of fleeces produced by range sheep. J. L. Lush and J. M. Jones. (Tex. Sta. Bul. 311, pp. 45, figs. 8. Sept., 1923.)

SWINE

Swine raising in Hawaii. F. G. Krauss. (Hawaii Sta. Bul. 48, pp. 43, figs. 26. May, 1923.)
The northern pig.—Its breeding and management. J. H. Shepperd. (N. Dak. Sta. Bul. 167, pp. 52, figs. 12. July, 1923.)
Swine feeding investigation, 1921–22. F. W. Bell, H. B. Winchester, and H. W. Marston. (Kans. Sta. Circ. 98, pp. 11, figs. 2. Oct., 1923.)
Swine feeding experiments. G. R. Warren and D. W. Williams. (Tex. Sta. Bul. 305, pp. 41, figs. 2. Feb., 1923.)
Swine feeding investigations.—Oklahoma feeds and how to prepare them. C. P. Thompson. (Okla. Sta. Bul. 148, pp. 8. Oct., 1923.)
Grazing and feeding trials with hogs. E. Barnett and C. J. Goodell. (Miss. Sta. Bul. 218, pp. 32, fig. 1. June, 1923.)
Feeding pigs on pasture. J. B. Rice. (Ill. Sta. Bul. 247, pp. 35–60, fig. 1. Jan., 1924.)
Supplemental specialty feeds for making 225-pound pigs on pasture. J. M. Evvard and C. C. Culbertson. (Iowa Sta. Circ. 85, pp. 8. May, 1923.)
Corn and soy beans for pork production. E. Barnett and C. J. Goodell. (Miss. Sta. Circ. 49, pp. 7. Apr., 1923.)
Rice bran and rice polish for growing and fattening pigs. G. R. Warren and D. W. Williams. (Tex. Sta. Bul. 313, pp. 18. Oct., 1923.)
Garbage for fattening pigs. F. S. Hultz and L. P. Reeve. (Wyo. Sta. Bul. 135, pp. 17–26, fig. 1. May, 1923.)
The value of buttermilk and lactic acid in pig feeding. J. B. Lindsey and C. L. Beals. (Mass. Sta. Bul. 217, pp. 61–67. Sept., 1923.)
Raising orphan pigs.—I, Protein modifications of cows' whole milk, frequency of feeding, nutritive ratio studies. J. M. Evvard, G. V. Glatfelter, and Q. W. Wallace. (Iowa Sta. Research Bul. 79, pp. 441–493, figs. 3. July, 1923.)
The value of mineral supplements in swine feeding. J. B. Rice and H. H. Mitchell. (Ill. Sta. Bul. 250, pp. 88–110. May, 1924.)
Self-feeders for fattening swine. L. A. Weaver. (Mo. Sta. Circ. 118, pp. 8, fig. 1. Apr., 1924.)

POULTRY

Poultry farming in New Jersey. A. G. Waller and W. C. Thompson. (N. J. Stas. Circ. 153, pp. 31, figs. 8. May, 1923.)
Organizing a poultry plant. G. G. Sawyer. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 12, pp. 4, fig. 1. Sept., 1923.)
Poultry breeding records. W. A. Lippincott. (Kans. Sta. Circ. 99, pp. 34, figs. 25. Oct., 1923.)
Experiments in close inbreeding in fowls. L. C. Dunn. (Conn. Storrs Sta. Bul. 111, pp. 137–172. Feb., 1923.)
The inheritance of fertility and hatchability in poultry. F. A. Hays and R. Sanborn. (Mass. Sta. Tech. Bul. 6, pp. 19–42. Jan., 1924.)
Pedigree, the basis of selecting breeding males for egg production. F. A. Hays and R. Sanborn. (Mass. Sta. Bul. 215, pp. 42–51, figs. 3. Apr., 1923.)
A method for distinguishing the sex of young chicks. L. C. Dunn. (Conn. Storrs Sta. Bul. 113, pp. 243–280, figs. 8. Mar., 1923.)
The value of various culling factors. G. W. Hervey. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 9, pp. 4. June, 1923.)
Poultry feeding in Montana. G. P. Goodearl. (Mont. Sta. Circ. 121, pp. 13. Dec., 1923.)
Feeding for egg production. L. E. Card. (Ill. Sta. Circ. 275, pp. 12, figs. 4. Nov., 1923.)
Feeding for egg production. H. L. Kempster. (Mo. Sta. Circ. 111, pp. 12, figs. 4. Apr., 1923.)
Feeding young chickens in confinement. L. C. Dunn. (Conn. Storrs Sta. Bul. 116, pp. 16, figs. 4. Mar., 1924.)
Influence of rations fed to growing chickens on the characteristics of the adult females. H. Atwood. (W. Va. Sta. Bul. 179, pp. 39, figs. 15. June, 1923.)
Animal protein for laying hens. W. F. Schoppe. (Mont. Sta. Bul. 161, pp. 10, fig. 1. Oct., 1923.)
Egg production, monthly costs and receipts on New Jersey poultry farms. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 4, pp. 4. Feb., 1924.)
The prediction of egg records. G. W. Hervey. (N. J. Stas. Bul. 389, pp. 20, figs. 10. Sept., 1923.)
Certain correlations in the weight and number of eggs and the weight of fowls. H. Atwood. (W. Va. Sta. Bul. 182, pp. 16, figs. 3. Aug., 1923.)
Changes in egg production in the station flock. H. D. Goodale. (Mass. Sta. Bul. 211, pop. ed., pp. 7, pl. 1. Oct., 1923.)
New Jersey's poultry exhibitions. W. C. Thompson. (N. J. Stas. Hints to Poultrymen, vol. 11, No. 11, pp. 4, fig. 1. Aug., 1923.)
Report of egg laying contests for 1923. R. R. Hannes and F. H. Clickner. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 3, pp. 4. Dec., 1923.)
Getting maximum results from the incubator. W. P. Thorp, jr. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 5, pp. 4, fig. 1. Feb., 1924.)
Temperature experiments during the incubation of hen eggs. A. G. Phillips and F. D. Brooks. (Ind. Sta. Bul. 275, pp. 16, figs. 5. Nov., 1923.)

Amount of carbon dioxide given off by eggs during incubation. H. Atwood and C. E. Weakley, jr. (W. Va. Sta. Bul. 185, pp. 15, figs. 5. Mar., 1924.)

Care and management of baby chicks. W. C. Thompson and N. R. Mehrhof. (N. J. Stas. Circ. 169, pp. 32, figs. 31. Mar., 1924.)

Brooding chicks artificially. J. E. Dougherty and S. S. Gossman. (Calif. Sta. Circ. 271, pp. 29, figs. 13. Oct., 1923.)

Brooding and feeding chicks. B. Alder. (Utah Sta. Circ. 50, pp. 16, figs. 3. Mar., 1924.)

Open air range house. F. L. Knowlton. (Oreg. Sta. Circ. 54, pp. 8, figs. 2. Jan., 1924.)

Why chicks die. W. H. Allen. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 7, pp. 4. Apr., 1924.)

Studies in egg preservation. D. B. Swingle and G. E. Poole. (Mont. Sta. Bul. 155, pp. 30, fig. 1. Feb., 1923.)

Turkey management. W. F. Schoppe. (Mont. Sta. Circ. 115, pp. 23, figs. 5. June, 1923.)

DAIRYING

Feeding and management of the dairy herd. W. B. Nevens. (Ill. Sta. Circ. 272, pp. 47, figs. 11. Aug., 1923.)

The feeding and management of dairy calves. E. V. Ellington and J. C. Knott. (Wash. Col. Sta. Bul. 178, pp. 31, figs. 10. Sept., 1923.)

A comparison of Jersey sires based on the average mature equivalent fat production of the daughters. C. W. Turner and A. C. Ragsdale. (Mo. Sta. Bul. 206, pp. 12, figs. 2. Oct., 1923.)

Feeding dairy cows. A. C. Ragsdale. (Mo. Sta. Circ. 115, pp. 12, figs. 4. Nov., 1923.)

Winter rations for dairy heifers. A. C. Ragsdale. (Mo. Sta. Circ. 116, pp. 8, figs. 7. Dec., 1923.)

Relation of the composition of rations on some New York dairy farms to the economics of milk production. E. G. Misner. (N. Y. Cornell Sta. Mem. 64, pp. 46, figs. 6. Feb., 1923.)

Better feeding for Indiana dairy cows. L. H. Fairchild and J. W. Wilbur. (Ind. Sta. Bul. 277, pp. 16, figs. 5. Jan., 1924.)

A comparison of roughages for milk production. A. C. McCandlish and E. Weaver. (Iowa Sta. Bul. 212, pp. 274–286. Mar., 1923.)

Soy bean v. alfalfa hay for milk production. E. L. Anthony and H. O. Henderson. (W. Va. Sta. Bul. 181, pp. 10, fig. 1. May, 1923.)

Velvet beans for dairy cows. J. P. Lamaster and I. R. Jones. (S. C. Sta. Bul. 216, pp. 16, figs. 4. Sept., 1923.)

Studies of dairy cattle.—II, Milk production. J. J. Hooper. (Ky. Sta. Bul. 248, pp. 63–85, figs. 4. July, 1923.)

Studies in milk secretion.—XIV, The effect of age on the milk yields and butterfat percentages of Guernsey advanced registry cattle. J. W. Gowen. (Me. Sta. Bul. 311, pp. 9–20, figs. 2. June, 1923.)

Studies on conformation in relation to milk producing capacity in cattle.—III, Conformation and milk yield in the light of the personal equation of the dairy cattle judge. J. W. Gowen. (Me. Sta. Bul. 314, pp. 67–96, fig. 1. Nov., 1923.)

The feed cost of milk and fat production as related to yields. H. A. Ross, H. F. Hall, and C. S. Rhode. (Ill. Sta. Bul. 244, pp. 551–573, figs. 3. May, 1923.)

The feed cost of milk and fat production as related to yields. H. A. Ross, H. F. Hall, and C. S. Rhode. Ill. Sta. Bul. 244, Abs. pp. 4. Aug., 1923.)

Relation between percentage fat content and yield of milk.—Correction of milk yield for fat content. W. L. Gaines and F. A. Davidson. (Ill. Sta. Bul. 245, pp. 577–621, figs. 11. June, 1923.)

Comparing the production records of cows.—Influence of quality (fat test) of milk on yield of milk. W. L. Gaines and F. A. Davidson. (Ill. Sta. Bul. 245, Abs., pp. 8, figs. 2. Dec., 1923.)

The practicability of the milking machine. J. L. Lush. (Tex. Sta. Circ. 30, pp. 23, figs. 2. Apr., 1923.)

Clean and cold milk. R. S. Breed. (N. Y. State Sta. Circ. 69, pp. 4, figs. 2.)

Testing milk and cream. W. P. Hays. [Mo. Sta. Circ. 119, pp. 11, figs. 16. Apr., 1924.)

A modification of the Babcock test for the determination of fat in buttermilk. P. H. Tracy and O. R. Overman. (Ill. Sta. Bul. 248, pp. 63–70. Jan., 1924.)

Pasteurization of market milk in the glass enameled tank and in-the-bottle. T. H. Wright, jr., (S. Dak. Sta. Bul. 203, pp. 19. June, 1923.)

The relation between the clumps of bacteria found in market milk and the flora of dairy utensils. W. A. Whiting. (N. Y. State Sta. Tech. Bul. 98, pp. 36. Nov., 1923.)

The colorimetric hydrogen-ion determination as a means of locating faulty methods at city milk plants. L. H. Cooledge. (Mich. Sta. Spec. Bul. 124, pp. 19, figs. 4. Sept., 1923.)

Paying for milk on a quality basis as a means of improving the supply. L. H. Cooledge and O. T. Goodwin. (Mich. Sta. Circ. 61, pp. 13, figs. 3. Sept., 1923.)

Factors affecting the butterfat test of cream samples. T. H. Broughton and R. L. Hammond. (Ind. Sta. Bul. 271, pp. 16, figs. 6. May, 1923.)

Better cream for butter making. V. C. Manhart. (Ind. Sta. Circ. 113, pp. 12. figs. 7. June, 1923.)

Some studies on the neutralization of cream for butter making. H. C. Jackson. (N. Y. Cornell Sta. Mem. 71, pp. 18. July, 1923.)

The volatile acids produced by starters and by organisms isolated from them. B. W. Hammer and F. F. Sherwood. (Iowa Sta. Research Bul. 80, pp. 15. July, 1923.)

The fishy flavor in butter. H. H. Sommer and B. J. Smit. (Wis. Sta. Research Bul. 57, pp. 51. Oct., 1923.)

The influence of manufacturing operations on the bacterial content of ice cream. F. W. Fabian and R. H. Cromley. (Mich. Sta. Tech. Bul. 60, pp. 24, fig. 1. Feb., 1923.)

How to produce ice cream with a low bacterial content. A. C. Fay and N. E. Olson. (Kans. Sta. Circ. 103, pp. 4. Feb., 1924.)

A simplified method of standardizing the ice cream mix. N. E. Olson. (Kans. Sta. Circ. 104, pp. 12, Mar., 1924.)

Ice cream ingredients. H. P. Davis, B. Mazurovsky, and J. A. Luithly. (Nebr. Sta. Circ. 22, pp. 22. Jan., 1924.)

DISEASES OF LIVESTOCK

Concerning blood complement. F. A. Rich. (Vt. Sta. Bul. 230, pp. 24, pls. 4. Mar., 1923.)

Foot-and-mouth disease. H. J. Frederick. (Utah Sta. Circ. 51, pp. 4. May, 1924.)

Bovine tuberculosis. L. Van Es. (Nebr. Sta. Circ. 23, pp. 66, pls. 11, figs. 5. Feb., 1924.)

Preliminary essentials to bovine tuberculosis control in California. G. H. Hart. (Calif. Sta. Circ. 264, pp. 8, figs. 3. May, 1923.)
Eradication of tuberculosis in cattle at the Kodiak Experiment Station. C. C. Georgeson and W. T. White. (Alaska Stas. Bul. 5, pp. 11, figs. 2. Jan., 1924.)
Avian type of tuberculosis in cattle: Injection and testing. C. Elder and A. M. Lee. (Wyo. Sta. Bul. 136, pp. 27–41, figs. 3. June, 1923.)
Concerning infectious abortion. F. A. Rich. (Vt. Sta. Bul. 231, pp. 32, figs. 2. Apr., 1923.)
The abortion problem in farm livestock. L. Van Es. (Nebr. Sta. Circ. 21, pp. 46, figs. 2. Sept., 1923.)
Infectious abortion in cattle. Calving and blood reaction records of thirteen herds. G. C. White, L. M. Chapman, and L. F. Rettger. (Conn. Storrs Sta. Bul. 112, pp. 175–240. Feb., 1923.)
The relation of high cellular counts to the *Bacterium abortus* infection of the udder. R. L. Tweed. (Mich. Sta. Tech. Bul. 61, pp. 28. Dec., 1923.)
Infectious abortion in swine. (Ill. Sta. Circ. 271, pp. 4, figs. 2. June, 1923.)
Bone chewing by cattle. H. Welch. (Mont. Sta. Circ. 122, pp. 8, figs. 2, Jan., 1924.)
Blackleg vaccines: Their production and use. J. P. Scott. (Kans. Sta. Tech. Bul. 10, pp. 24. June, 1923.)
The more important poultry diseases. L. Van Es and H. M. Martin. (Nebr. Sta. Bul. 195, pp. 71, figs. 15. Oct., 1923.)
Diseases of baby chicks. F. R. Beaudette. (N. J. Stas Hints to Poultrymen, vol. 12, No. 6, pp. 4, figs. 2. Mar., 1924.)
Bacillary white diarrhea. A. J. Steiner. (Ky. Sta. Circ. 33, pp. 8. Apr., 1924.)
Bacillary white diarrhea of chicks. (Ill. Sta. Circ. 273, pp. 4, figs. 5. Sept., 1923.
Control of bacillary white diarrhea, 1922–1923. G. E. Gage and O. S. Flint. (Mass. Sta. Control Ser. Bul. 23, pp. 10, fig. 1. Sept., 1923.)
A description of the method of collecting blood samples from breeding stock to be tested for "carriers" of bacillary white diarrhea. F. R. Beaudette. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 9, pp. 4. June, 1924.)
Clostridium botulinum type C—A pathogenic anaerobe associated with a limberneck-like disease in chickens and ducks. R. Graham and I. B. Boughton. (Ill. Sta. Bul. 246, pp. 34, figs. 9. Oct., 1923.)
Blackhead in turkeys. H. Welch. (Mont. Sta. Circ. 117, pp. 7, figs. 3. Sept., 1923.
Vitamins and their relation to poultry diseases. F. R. Beaudette. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 2, pp. 4, figs. 2. Nov., 1923.)
Necrobacillosis. G. H. Glover. (Colo. Sta. Bul. 289, pp. 12, figs. 3. Nov., 1923.)
History of a "swamp fever" virus carrier. A. F. Schalk and L. M. Roderick. (N. Dak. Sta. Bul. 168, pp. 14, pl. 1, figs. 6. Aug., 1923.)
Two common weeds that cause death. A. A. Hansen. (Ind. Sta. Circ. 110, pp. 8, figs. 4. Feb., 1923.)
The spring rabbit brush, a range plant poisonous to sheep. C. E. Fleming, M. R. Miller, and L. R. Vawter. (Nev. Sta. Bul. 104, pp. 29, figs. 12. Sept., 1922.)
The low larkspur, a plant of the spring range poisonous to cattle. C. E. Fleming, M. R. Miller, and L. R. Vawter. (Nev. Sta. Bul. 105, pp. 22, pl. 1, figs. 8. Apr., 1923.)
White snakeroot poisoning in livestock. L. P. Doyle and F. L. Walkey. (Ind. Sta. Bul. 270, pp. 15, figs. 11. May, 1923.)
Control of the whorled milkweed in Colorado. W. L. May. (Colo. Sta. Bul. 285, pp. 24, figs. 8. Apr., 1923.)

AGRICULTURAL ENGINEERING

Plans for small barns. L. J. Smith. (Wash. Col. Sta. Pop. Bul. 123, pp. 26, figs. 26. Apr., 1923.)
Building plans and bill of materials for O. A. C. 400-hen laying house. F. L. Knowlton. (Oreg. Sta. Circ. 51, pp. 8, figs. 4. Nov., 1923.)
The O. A. C. portable colony house. A. G. Lunn. (Oreg. Sta. Circ. 52, pp. 8, figs. 3. Dec., 1923.)
How to convert the O. A. C. portable colony house into a brooder house. A. G. Lunn. (Oreg. Sta. [Leaflet], pp. 2, fig. 1. Dec., 1923.)
The New Jersey multiple brooder house. W. P. Thorp, jr. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 8, pp. 4, fig. 1. May, 1924.)
Inexpensive labor saving poultry appliances. J. E. Dougherty and S. S. Gossman. (Calif. Sta. Circ. 268, pp. 32, figs. 46. July, 1923.)
The pit silo. J. W. Sjogren. (Colo. Sta. Bul. 288, pp. 12, figs. 9. Oct., 1923.)
An orchard brush burner. W. L. Zink. (Calif. Sta. Circ. 269, pp. 10, figs. 11. Aug., 1923.)
A farm septic tank. W. B. Herms and H. L. Belton. (Calif. Sta. Circ. 270, pp. 16, figs. 15. Sept., 1923.)
The septic tank and tile sewage disposal system. H. H. Musselman and O. E. Robey. (Mich. Sta. Spec. Bul. 119, pp. 23, figs. 14. Aug., 1923.)
Studies on the biology of sewage disposal. W. Rudolfs. (N. J. Stas. Bul. 390, pp. 78, figs. 33. July, 1923.)
Tractors in Arkansas. D. G. Carter. (Ark. Sta. Bul. 186, pp. 18, figs. 7. June, 1923.)
Tractor farming in New Jersey. E. R. Gross and A. G. Waller. (N. J. Stas. Bul. 386, pp. 24, figs. 7. May, 1923.)
Dust and tractor engine. A. H. Hoffman. (Calif. Sta. Bul. 362, pp. 469–486, figs. 8. May, 1923.)
The tendency of tractors to rise in front; causes and remedies. A. H. Hoffman. (Calif. Sta. Circ. 267, pp. 8, figs. 8. June, 1923.)
Stationary spray plants. O. M. Morris. (Wash. Col. Sta. Pop. Bul. 125, pp. 20, figs. 10. Jan., 1924.)
The simplex lime spreader. H. H. Musselman. (Mich. Sta. Circ. 62, pp. 7, figs. 5. Mar., 1924)
"Dry rot" in buildings and building material. C. W. Edgerton. (La. Stas. Bul. 190, pp. 12, figs. 5. Apr., 1924.)
Studies on the treatment and disposal of dairy wastes. C. L. Walker et al (N. Y. Cornell Sta. Bul. 425, pp. 170, pls. 18, figs. 19. Nov., 1923.)
Report of road materials project. O. V. Adams. (Colo. Sta. Bul. 284, pp. 46. Apr., 1923.)
Concrete fence posts. J. B. Davidson. (Iowa Sta. Bul. 219, pp. 17–44, figs. 29. Jan., 1924.
An economical farm level. L. J. Smith. (Wash. Col. Sta. Pop. Bul. 124, pp. 11, figs. 6. Dec., 1923.)
Design and construction of small concrete-lined canals. W. E. Code. (Ariz. Sta. Bul. 97, pp. 37, figs. 23. Sept., 1923.)

Selected list of references relating to irrigation in California. R. Venable. (Calif. Sta. Circ. 260, pp. 64. Apr., 1923.)

RURAL ECONOMICS

Cost accounts for six years on some successful New York farms. G. F. Warren et al. (N. Y. Cornell Sta. Bul. 414, pp. 139, fig. 1. Feb., 1923.)
A study of the cost of producing wheat and oats in central and southern Indiana. M. H. Overton. (Ind. Sta. Bul. 272, pp. 24, figs. 6. June, 1923.)
The cost of producing market milk and butterfat on 246 California dairies. R. L. Adams. (Calif. Sta. Bul. 372, pp. 164, figs. 20. Nov., 1923.)
Cost of producing pork. E. L. Potter, H. A. Lindgren, and A. W. Oliver. (Oreg. Sta. Circ. 56, pp. 12, figs. 3. May, 1924.)
Prices of Ohio farm products. J. I. Falconer. (Ohio Sta. Bul. 365, pp. 99–143, figs. 10. June, 1923.)
Factors affecting the price of farm products. H. C. Filley. (Nebr. Sta. Bul. 198, pp. 40, figs. 14. Nov., 1923.)
Egg prices and cold storage holdings. G. W. Hervey. (N. J. Stas. Hints to Poultrymen, 11 (1923), No. 10, pp. 4, figs. 3. July, 1923.)
Adjusting production to meet home market demands in Blair County, Pa. R. B. Dunlap, B. H. Critchfield, and M. V. Carroll. (Pa. Sta. Bul. 184, pp. 51, figs. 16. Jan., 1924.)
The marketing of Kentucky blue grass and orchard grass seeds. D. G. Card. (Ky. Sta. Bul. 247, pp. 33–61, figs. 6. June, 1923.)
Marketing milk in six cities of Kansas. F. L. Thomsen. (Kans. Sta. Bul. 230, pp. 32, figs. 9. Nov., 1923.)
Some lessons from production records. G. W. Hervey. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 1, pp. 4, Oct., 1923.)
A farm account manual for New Jersey farmers. H. Keller, jr. (N. J. Stas. Circ. 160, pp. 31, figs. 33. Nov., 1923.)
Economic studies of dairy farming in New York.—I, Condensery milk without cash crops. E. G. Misner. (N. Y. Cornell Sta. Bul. 421, pp. 79, figs. 9. June, 1923.)
A study of farm organization in southwestern Minnesota. G. A. Pond and J. W. Tapp. (Minn. Sta. Bul. 205, pp. 135, figs. 30. Nov., 1923.)
A farm-management study of the Great Salt Lake Valley. G. Stewart. (Utah Sta. Bul. 184, pp. 44, figs. 13. May, 1923.)
Drainage district farms in central Wisconsin. E. R. Jones and B. G. Packer. (Wis. Sta. Bul. 358, pp. 48, figs. 30. Oct., 1923.)
Why some farms pay. P. E. McNall. (Wis. Sta. Bul. 364, pp. 23, figs. 7. June, 1924.)
Report of a farm credit survey of four townships, Foster County, N. Dak. R. E. Willard. (N. Dak. Sta. Bul. 175, pp. 26. Feb., 1924.)
Rural credits in Utah. E. B. Brossard. (Utah Sta. Circ. 48, pp. 42, fig. 1. Sept., 1923.)
Cash and share renting of farms. A. H. Benton. (N. Dak. Sta. Bul. 171, pp. 51, figs. 11. Feb., 1924.)
Drawing up the farm lease. C. L. Holmes. (Iowa Sta. Circ. 87, pp. 32. Aug., 1923.)
Farm rental terms. H. E. Selby. (Mont. Sta. Circ. 119, pp. 16. Nov., 1923.)
California farm tenancy and methods of leasing. R. L. Adams. (Calif. Sta. Circ. 272, pp. 48. Nov., 1923.)
Relation of types of tenancy to types of farming in Iowa. C. L. Holmes. (Iowa Sta. Bul. 214, pp. 323–364, figs. 14. May, 1923.)
The social aspects of rural life and farm tenantry, Cedar County, Iowa. G. H. Von Tungeln, E. L. Kirkpatrick, C. R. Hoffer, and J. F. Thaden. (Iowa Sta. Bul. 217, pp. 433–494, figs. 21. Aug., 1923.)
Nebraska farm tenancy—Some community phases. J. O. Rankin. (Nebr. Sta. Bul. 196, pp. 50, figs. 25. Oct., 1923.)
The movement of farm population. E. C. Young. (N. Y. Cornell Sta. Bul. 426, pp. 95, figs. 7. Mar., 1924.)
Nebraska farm homes. J. O. Rankin. Nebr. Sta. Bul. 191, pp. 48, figs. 20. May, 1923.)
Costs of family living on the farm. O. R. Johnson. (Mo. Sta. Bul. 213, pp. 20, figs. 9. May, 1924.)
A social study of Ravalli County, Mont. W. H. Baumgartel. (Mont. Sta. Bul. 160, pp. 32, figs. 17. Sept., 1923.)
The social areas of Otsego County. D. Sanderson and W. S. Thompson. (N. Y. Cornell Sta. Bul. 422, pp. 40, pls. 3, figs. 6. July, 1923.)
The standard of life in a typical section of diversified farming. E. L. Kirkpatrick. (N. Y. Cornell Sta. Bul. 423, pp. 133, figs. 24. July, 1923.)
Service relations of town and country. J. H. Kolb. (Wis. Sta. Research Bul. 58, pp. 78, figs. 18. Dec., 1923.)
Baking club manual. B. E. Scholes and H. M. Phillips. (Ill. Sta. Circ. 267, pp. 56, figs. 11. May, 1923.)
Table service and etiquette for the home. C. H. Plunkett. (Ark. Sta. Bul. 188, pp. 21, figs. 5. July, 1923.)

REPORTS, REGULATORY AND MISCELLANEOUS PUBLICATIONS

REPORTS

Thirty-fourth annual report of the agricultural experiment station of the Alabama Polytechnic Institute, Auburn, Alabama, 1923. pp. 12.
Report of the Alaska Agricultural Experiment Stations, 1922. C. C. Georgeson et al. pp. 25, pls. 2, figs. 7.
The thirty-sixth annual report of the Colorado Agricultural Experiment Station for the year 1923. C. P. Gillette et al. pp. 40.
Report of the director for the year ending October 31, 1923. W. L. Slate, jr. (Conn. State Sta. Bul. 254, pp. 141–159. Jan., 1924.)
Annual report of the director for the fiscal year ending June 30, 1923. C. A. McCue et al. (Del. Sta. Bul. 135, pp. 48, fig. 1. Jan., 1924.)
Report of the [Florida Agricultural Experiment Station] for the fiscal year ending June 30, 1922. pp. 75R + VI, figs. 12.
Thirty-sixth annual report Georgia Experiment Station for the year 1923. H. P. Stuckey. pp. 33–57, figs. 3.
Work and progress of the agricultural experiment station for the year ended December 31, 1922. (Idaho Sta. Bul. 131, pp. 71. Jan., 1923.)
Thirty-sixth annual report of the Purdue University Agricultural Experiment Station, La Fayette, Ind., for the year ending June 30, 1923. G. I. Christie and H. J. Reed. pp. 79, figs. 29.

Annual report for fiscal year ending June 30, 1922, agricultural experiment station, Iowa State College of Agriculture and Mechanic Arts. C. F. Curtiss. pp. 64.

Annual report for the fiscal year ending June 30, 1923, agricultural experiment station, Iowa State College of Agriculture and Mechanic Arts. C. F. Curtiss. pp. 63.

Thirty-fourth annual report of the agricultural experiment stations of the Louisiana State University and Agricultural and Mechanical College for 1922. W. R. Dodson et al. pp. 47.

Thirty-fifth annual report of the agricultural experiment stations of Louisiana State University and Agricultural and Mechanical College for 1923. W. R. Dodson et al. pp. 61.

The thirty-sixth annual report of the University of Maryland Agricultural Experiment Station, 1922–23. H. J. Patterson. pp. xxii + 86 + 2, fig. 1.

Thirty-fifth annual report of the Massachusetts Agricultural Experiment Station, 1922. Part I, pp. 25a; Part II, pp. 163, pls. 16, figs. 71.

Thirty-fifth annual report of the experiment station of the Michigan Agricultural College under the Hatch and Adams Acts for the year ending June 30, 1922. pp. 161–672, figs. 160.

Thirtieth annual report of the [Minnesota] Agricultural Experiment Station, July 1, 1921, to June 30, 1922. W. C. Coffey et al. pp. 151, figs. 10.

Biennial report of the Missouri State Fruit Experiment Station, Mountain Grove, Mo., 1921–1922. F. W. Faurot. pp. 7.

Contributions to knowledge in agriculture. One year's work, agricultural experiment station (report of the director, July 1, 1922, to June 30, 1923). F. B. Mumford. (Mo. Sta. Bul. 210, pp. 77, figs. 21. Feb., 1924.)

Twenty-ninth annual report [Montana Agricultural Experiment Station] for the fiscal year ending June 30, 1922. F. B. Linfield et al. pp. 38.

Thirty-sixth annual report of the agricultural experiment station of Nebraska, 1922. E. A. Burnett. pp. 96, figs. 10.

Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1922. pp. 20, figs. 2.

Forty-third annual report of the New Jersey State Agricultural Experiment Station and the thirty-fifth annual report of the New Jersey Agricultural College Experiment Station for the year ending June 30, 1922. J. G. Lipman et al. pp. 600, pls. 37, figs. 27.

Thirty-fourth annual report, agricultural experiment station of the New Mexico College of Agriculture and Mechanic Arts, 1922–23. pp. 50, figs. 2.

Thirty-sixth annual report of the New York State College of Agriculture at Cornell University and of the Agricultural Experiment Station, 1923. A. R. Mann. pp. 104.

Forty-second annual report [of the New York State Agricultural Experiment Station] for the fiscal year ended June 30, 1923. R. W. Thatcher. pp. 50.

Forty-fifth annual report of the North Carolina Agricultural Experiment Station, fiscal year ending June 30, 1922. B. W. Kilgore et al. pp. 88.

Forty-second annual report for 1922–23. C. G. Williams. (Ohio Sta. Bul. 373, pp. 92 + [6], figs. 9. June, 1923.)

Thirty-sixth annual report of the director for the fiscal year ending June 30, 1923. (Pa. Sta. Bul. 181, pp. 28, fig. 1. Sept., 1923.)

Report of the Porto Rico Agricultural Experiment Station, 1922. D. W. May et al. pp. 18, pls. 4, figs. 6.

Thirty-sixth annual report of the South Carolina Experiment Station for the year ended June 30, 1923. pp. 74, figs. 22.

Annual report of the director [South Dakota] Agricultural Experiment Station for the fiscal year ending June 30, 1923. J. W. Wilson et al. pp. 36.

Twenty-ninth annual report of the agricultural experiment station of the University of Tennessee for 1916. H. A. Morgan et al. pp. 18, fig. 1.

Thirtieth annual report of the agricultural experiment station of the University of Tennessee for 1917. H. A. Morgan et al. pp. 14, fig. 1.

Thirty-first annual report of the agricultural experiment station of the University of Tennessee for 1918. H. A. Morgan et al. pp. 16, figs. 2.

Thirty-second annual report of the agricultural experiment station of the University of Tennessee for 1919. C. A. Mooers et al. pp. 20, figs. 3.

Thirty-third annual report of the agricultural experiment station of the University of Tennessee for 1920. C. A. Mooers et al. pp. 18, fig. 1.

Thirty-fourth annual report of the agricultural experiment station of the University of Tennessee for 1921. C. A. Mooers et al. pp. 19, fig. 1.

Thirty-fifth annual report of the agricultural experiment station of the University of Tennessee for 1922. C. A. Mooers et al. pp. 22, fig. 1.

Report of the Virgin Islands Agricultural Experiment Station, 1922. J. B. Thompson et al. pp 18, pls. 4, figs. 4.

Thirty-third annual report for the fiscal year ended June 30, 1923. E. C. Johnson. (Wash. Col. Sta. Bul. 180, pp. 80. Dec., 1923.)

New facts in farm science.—The fortieth annual report of the director, 1922–23. H. L. Russell and F. B. Morrison. (Wis. Sta. Bul. 362, pp. 115, figs. 40. Mar., 1924.)

Thirty-third annual report of the University of Wyoming Agricultural Experiment Station, 1922–23. J. A. Hill. pp. 43–74, fig. 1.

First report of the tobacco substation at Windsor, Conn. G. A. Hopson. (Conn. State Sta. [Leaflet], pp. 4.)

Report of Moses Fell Annex, Bedford, Ind., June, 1924. H. J. Reed and E. W. Moore. (Ind. Sta. Circ. 117, pp. 20, figs. 15. June, 1924.)

Report of Northeast Demonstration Farm and Experiment Station, Duluth, [Minn.] 1922 and 1923. M. J. Thompson. pp. 36, figs. 9.

Report of Northwest Experiment Station, Crookston, Minn., 1922. C. G. Selvig and R. S. Dunham. pp. 101, figs. 26.

Report of West Central Experiment Station, Morris, Minn., 1922. P. E. Miller. pp. 55, figs. 5.

Report Delta Branch Experiment Station, 1922 and 1923. W. E. Ayres. (Miss. Sta. Bul. 221, pp. 15. Jan., 1924.)

Report from Holly Springs Branch Experiment Station for 1923. C. T. Ames. (Miss. Sta. Bul. 220, pp. 24, figs. 2. Dec., 1923.)

County experiment farms in Ohio.—I, The Miami County Experiment Farm. (Ohio Sta. Bul. 361, pt. I, pp. 314–343, fig. 1. June, 1922.)

County experiment farms in Ohio.—II, The Paulding County Experiment Farm. (Ohio Sta. Bul. 361, pt. II, pp. 346–375, figs. 3. June, 1922.)

County experiment farms in Ohio.—III, The Clermont County Experiment Farm. (Ohio Sta. Bul. 361, pt. III, pp. 377–412, figs. 3. June, 1922.)

County experiment farms in Ohio.—IV, The Hamilton County Experiment Farm. (Ohio Sta. Bul. 361, pt. IV, pp. 414–438, fig. 1. June, 1922.)

County experiment farms in Ohio.—V, The Washington County Experiment Farm. (Ohio Sta. Bul. 361, pt. V, pp. 440–473, fig. 1. June, 1922.)

County experiment farms in Ohio.—VI, The Trumbull County Experiment Farm. (Ohio Sta. Bul. 361, pt. VI, pp. 475–498. June, 1923.)

County experiment farms in Ohio.—VII, The Mahoning County Experiment Farm. (Ohio Sta. Bul. 361, pt. VII, pp. 500–525. June, 1922.)

County experiment farms in Ohio.—VIII, The Belmont County Experiment Farm. (Ohio Sta. Bul. 361, pt. VIII, pp. 528–541. June, 1922.)

County experiment farms in Ohio.—IX, The Madison County Experiment Farm. (Ohio Sta. Bul. 361, pt. IX, pp. 544–563. June, 1922.)

Twenty-second report of the State Entomologist for 1922. W. E. Britton. (Conn. State Sta. Bul. 247, pp. 265–381, pls. 16, figs. 8. 1923.)

Purdue handbook of agricultural facts, 1924. (Ind. Sta., pp. 223, figs. 35.)

Abstracts of papers not included in bulletins, finances, meteorology, index. (Me. Sta. Bul. 309, pp. [2]+93–104+X. Dec., 1922.)

An agricultural program for Montana. A. Atkinson. (Mont. Sta. [pamphlet]. pp. 13. [1924].)

Progress of agricultural experiments, 1923. J. C. Kendall. (N. H. Sta. Bul. 212, pp. 38. Jan., 1924.)

A few facts about the station and its work. (N. Y. State Sta. [pamphlet], pp. 23, figs. 20.)

PERIODICAL BULLETINS

Quarterly Bulletin, Michigan Agricultural Experiment Station.—Vol. 6 (1923), No. 1, pp. 38, figs. 14; No. 2, pp. 41–78, figs. 10; (1924), No. 3, pp. 82–143, figs. 16; No. 4, pp. 145–199, figs. 17.

Farmers' Market Bulletin, North Carolina Agricultural Experiment Station.—Vol. 10 (1923), No. 63, pp. 8; No. 64, pp. 8; No. 65, pp. 12, figs. 2; No. 66, pp. 8; (1924), No. 67, pp. 11; No. 68, pp. 8.

Monthly Bulletin, Ohio Agricultural Experiment Station.—Vol. 8 (1923), No. 5–6, pp. 65–96, figs. 6; No. 7–8, pp. 97–128, figs. 2; No. 9–10, pp. 129–160, figs. 11; No. 11–12, pp. 161–191, figs. 12; Vol. 9 (1924), No. 1–2, pp. 32, figs. 18.

Bi-monthly Bulletin, Western Washington Experiment Station, Puyallup, Wash.—Vol. 11 (1923), No. 3, pp. 50–64; No. 4, pp. 65–88, figs. 4; No. 5, pp. 89–112, figs. 3; (1924), No. 6, pp. 113–136; Vol. 12, No. 1, pp. 24.

REGULATORY BULLETINS—FEEDING STUFFS

Report on commercial feeding stuffs, 1922. E. M. Bailey. (Conn. State Sta. Bul. 249, pp. 445–475. Apr., 1923.)

Commercial feeding stuffs. E. G. Proulx et al. (Ind. Sta. Bul. 268, pp. 23, figs. 2. Apr., 1923; Bul. 278, pp. 23. Apr., 1924.)

Feeds and their use—Inspection and analyses. J. D. Turner, H. D. Spears, and E. L. Jackson. (Ky. Sta. Bul. 249, pp. 87–327. Oct., 1923.)

Commercial feeding stuffs, 1922–23. J. M. Bartlett. (Me. Sta. Off. Insp. 108, pp. 9–28. Aug., 1923.)

Inspection of commercial feed stuffs. P. H. Smith and F. J. Kokoski. (Mass. Sta. Control Ser. Bul. 24, pp. 32. Nov., 1923.)

Inspection of commercial feeding stuffs. H. R. Kraybill and T. O. Smith. (N. H. Sta. Bul. 209, pp. 44. Aug., 1923.)

Analyses of commercial feeding stuffs and registrations for 1923. C. S. Cathcart. (N. J. Stas. Bul. 387, pp. 70, fig. 1. Aug., 1923.)

Composition of official samples of feeding stuffs and mixtures collected in New York from January to July, 1923. L. L. Van Slyke. (N. Y. State Sta. Bul. 515, pp. 18. Feb., 1924.)

Inspection of feeds. J. B. Smith and W. L. Adams. (R. I. Sta. Ann. Feed Circ., pp. 12. Apr., 1924.)

Commercial feeding stuffs, September 1, 1922, to August 31, 1923. B. Youngblood, F. D. Fuller, and S. D. Pearce. (Tex. Sta. Bul. 314, pp. 134. Nov., 1923.)

Commercial feeding stuffs. J. L. Hills, C. H. Jones, and G. F. Anderson. (Vt. Sta. Bul. 236, pp. 31. Sept., 1923.)

REGULATORY BULLETINS—FERTILIZERS

Fertilizer report for 1923. E. M. Bailey. (Conn. State Sta. Bul. 250, pp. 88. Nov., 1923.)

Commercial fertilizers. E. G. Proulx et al. (Ind. Sta. Bul. 269, pp. 64, fig. 1. May, 1923.)

Analyses of commercial fertilizers. H. E. Curtis, H. R. Allen, and L. Gault. (Ky. Sta. Bul. 245, pp. 297–378. Dec., 1922.)

Commercial fertilizers, 1923. J. M. Bartlett. (Me. Sta. Off. Insp. 109, pp. 29–52. Oct., 1923.)

Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and S. J. Broderick. (Mass. Sta. Control Ser. Bul. 25, pp. 31, figs. 4. Nov., 1923.)

The Missouri fertilizer law. F. B. Mumford and L. D. Haigh. (Mo. Sta. Circ. 114, pp. 4. Oct., 1923.)

Inspection of commercial fertilizers for 1923. H. R. Kraybill, T. O. Smith, and C. P. Spaeth. (N. H. Sta. Bul. 210, pp. 16. Oct., 1923.)

Analyses of commercial fertilizers, fertilizer supplies, and home mixtures for 1923. C. S. Cathcart. (N. J. Stas. Bul. 393, pp. 37. Nov., 1923.)

Analyses of commercial fertilizers and ground bone; analyses of agricultural lime, 1923. C. S. Cathcart. (N. J. Stas. Bul. 395, pp. 38. Dec., 1923.)

Fertilizer registrations for 1924. C. S. Cathcart. (N. J. Stas. Bul. 396, pp. 27. Jan., 1924.)

Composition and prices of commercial fertilizers in New York in 1923. L. L. Van Slyke. (N. Y. State Sta. Bul. 511, pp. 16. Feb., 1924.)

Inspection of fertilizers. P. S. Burgess and J. B. Smith. (R. I. Sta. Ann. Fert. Circ., pp. 13. Oct., 1923.)

Analyses of commercial fertilizers. R. N. Brackett. (S. C. Sta. Bul. 217, pp. 58. Aug., 1923.)

Commercial fertilizers in 1922–23. G. S. Fraps and S. E. Asbury. (Tex. Sta. Bul. 312, pp. 35. Sept., 1923.)

Commercial fertilizers. J. L. Hills, C. H. Jones, and G. F. Anderson. (Vt. Sta. Bul. 234, pp. 24. July, 1923.)

REGULATORY BULLETINS—SEEDS

Report of the seed commissioner for the biennium 1921–22. C. B. Ahlson. (Idaho Sta. Circ. 31, pp. 16, figs. 2. Jan., 1923.)
Inspection of agricultural seeds. E. G. Proulx et al (Ind. Sta. Bul. 276, pp. 72, figs. 3. Jan., 1924.)
Testing agricultural seeds. W. O. Whitcomb. (Mont. Sta. Circ. 114, pp. 17, figs. 10. May, 1923.)
Results of seed tests for 1923. M. G. Eastman (N. H. Sta. Bul. 211, pp. 16. Dec., 1923.)
Results of seed and legume inoculant inspection for 1923. J. G. Fiske. (N. J. Stas. Bul. 377, pp. 73. Jan., 1923; Bul. 397, pp. 67. Mar., 1924.)
Work of the seed testing laboratory from 1918 to 1923, with notes on seed quality, seed testing, seed law compliance, and trade practices. M. T. Munn and E. F. Hopkins. (N. Y. State Sta. Bul. 504, pp. 35. Nov., 1923.)
North Dakota pure seed law.—Interpretations and suggestions. H. L. Bolley and O. A. Stevens. (N. Dak. Sta. Circ. 20 (Rev. of Spec. Seed Bul. 2), pp. 7. July, 1923.)
Seed certification and listing. H. L. Bolley and O. A. Stevens. (N. Dak. Sta. Circ. 21 (Rev. of Pure Seed Circ. 10), pp. 4, figs. 2. July, 1923.)
How to use the seed laboratory. O. A. Stevens. (N. Dak. Sta. Circ. 22, pp. 12, figs. 5. Oct., 1923.)
Agricultural seed inspection. A. S. Lutman. (Vt. Sta. Bul. 233, pp. 8. Oct., 1923.)

REGULATORY BULLETINS—MISCELLANEOUS

Report of the Connecticut Agricultural Experiment Station, New Haven, Conn., on food products and drugs, 1922. Part II. E. M. Bailey. (Conn. State Sta. Bul. 248, pp. 383–443. Mar., 1923.)
Foods and drugs. J. M. Bartlett. (Me. Sta. Off. Insp. 107, pp. 8. Apr., 1923.)
Insecticides and fungicides, 1923. J. M. Bartlett. (Me. Sta. Off. Insp. 110, pp. 53–60. Dec., 1923.)
Analysis of materials sold as insecticides and fungicides during 1923. C. S. Cathcart, R. L. Willis, and L. R. Smith. (N. J. Stas. Bul. 392, pp. 18, fig. 1. Oct., 1923.)
Inspection of lime products used in agriculture. H. D. Haskins, L. S. Walker, and S. J. Broderick. (Mass. Sta. Control Ser. Bul. 26, pp. 6, fig. 1. Dec., 1923.)
Kansas State Live Stock Registry Board. (Kans. Sta. Insp. Circ. 13, pp. 119, figs. 3. Dec., 1920.)
Stallion enrollment.—XII, Report of stallion enrollment work for the year 1923, with lists of stallions and jacks enrolled. (Ind. Sta. Circ. 116, pp. 55. Dec., 1923.)
Stallion registration work in Kansas. (Kans. Sta. Insp. Circ. 20, pp. 3. Dec., 1922.)
Ninth annual report of the dairy department creamery license division for the year ending March 31, 1923. R. L. Hammond. (Ind. Sta. Circ. 111, pp. 19, figs. 2. June, 1923.)
Creamery inspection in New Jersey. Fourth annual report for the year ending June 30, 1923. F. C. Button. (N. J. Stas. Circ. 157, pp. 16, figs. 2. Sept., 1923.)

PUBLICATION LISTS AND MISCELLANEOUS

Publications available for free distribution. (Idaho Sta. Circ. 36, pp. 4. Jan., 1924.)
Author index of the publications of the Pennsylvania Agricultural Experiment Station. W. Frear and T. I. Mairs. (Pa. Sta. Bul. 180, pp. 56. Aug., 1923.)
Guide to station buildings and fields. (N. Y. State Sta. Circ. 68, pp. 4, figs. 3. [1923.].)
The use of explosives in agriculture. E. R. Cross. (N. J. Stas. Circ. 159, pp. 8, figs. 13. Nov., 1923.)
Comparison of woods for butter boxes. G. D. Turnbow. (Calif. Sta. Bul. 369, pp. 10, figs. 5. Aug., 1923.)
Sewing grain sacks. J. Koeber. (Calif. Sta. Circ. 261, pp. 11, figs. 15. Apr., 1923.)

STATISTICS OF THE STATIONS

By J. I. Schulte

For the fiscal year ended June 30, 1924, the total income from all sources reported by the experiment stations was $10,239,074.56, this amount including $1,440,000 Federal funds under the Hatch and Adams Acts and $205,000 appropriated by the Federal Government for the experiment stations in Alaska and the insular possessions. The support received by the stations from within the States included $6,115,027.20 derived from State appropriations or apportionments, $420,071.78 from fees, $1,318,839.89 from the sale of farm and other products, $164,395.42 from miscellaneous sources, and $575,740.27 carried over as balances from the previous year.

The value of additions to the equipment of the stations during the year was reported as follows:

Buildings	$1,381,638.48
Library	43,548.77
Apparatus	133,029.31
Farm implements	$171,955.27
Livestock	161,514.53
Miscellaneous	122,099.62
Total	2,013,785.98

In the work of administration and inquiry the experiment stations employed 2,385 persons. Of these 1,158 were also members of the teaching staffs of the colleges and 566 assisted in the various lines of extension work. During the year the stations issued 836 publications, including annual reports, bulletins, circulars, and press bulletins aggregating 24,602 pages. These were distributed to 930,364 addresses on regular mailing lists in addition to the number sent in response to special requests.

The statistics of the stations by States are given in the tables following:

General statistics, 1924

Station	Location	Director	Date of original organization	Date of organization under Hatch Act	Number on staff	Number of teachers on staff	Number of persons on staff who assist in extension work	Publications during fiscal year 1923–24: Number	Publications during fiscal year 1923–24: Pages	Number of names on mailing list
Alabama (College)	Auburn	M. J. Funchess	Feb. —, 1883	Feb. 24, 1888	28	13	3	10	152	1,935
Alabama (Canebrake)	Uniontown	W. A. Cammack	Jan. 1, 1886	Apr. 1, 1888	1					
Alabama	Tuskegee Institute	G. W. Carver	Feb. 15, 1897		5					
Alaska	Sitka	C. C. Georgeson			8			4	67	3,000
Arizona	Tucson	J. J. Thornber		—, 1889	21	20	4	9	223	6,600
Arkansas	Fayetteville	Dan T. Gray		—, 1887	28	21		8	235	12,620
California	Berkeley	E. D. Merrill	—, 1875	Mar. —, 1888	151	108	88	42	1,858	42,538
Colorado	Fort Collins	C. P. Gillette		Feb. 29, 1888	44	23	15	9	248	900
Connecticut (State)	New Haven	W. L. Slate, jr	Oct. 1, 1875	May 18, 1887	32	1		10	544	9,912
Connecticut (Storrs)	Storrs	do		May 18, 1887	14	8		10	414	9,000
Delaware	Newark	C. A. McCue		Feb. 21, 1888	14	9	5	4	134	7,380
Florida	Gainesville	Wilmon Newell		—, 1888	21	1	10	13	240	18,000
Georgia	Experiment	H. P. Stuckey	Feb. 18, 1888	July 1, 1889	9			23	135	6,000
Guam	Guam	C. W. Edwards			4					
Hawaii	Honolulu	J. M. Westgate			6	2	5	2	40	1,172
Idaho	Moscow	E. J. Iddings		Feb. 26, 1892	36	16	6	11	60	14,506
Illinois	Urbana	H. W. Mumford		Mar. 21, 1888	101	73	30	25	618	23,000
Indiana	Lafayette	G. I. Christie	—, 1885	Jan. —, 1888	78	19		37	670	35,870
Iowa	Ames	C. F. Curtiss		Feb. 17, 1888	86	25		37	1,219	40,250
Kansas	Manhattan	F. D. Farrell		Feb. 8, 1888	80	42		14	399	12,000
Kentucky	Lexington	T. P. Cooper	Sept. —, 1885	Apr. —, 1888	59	24	7	13	667	10,000
Louisiana (Sugar)	New Orleans	W. R. Dodson	Sept. —, 1885							
Louisiana (State)	Baton Rouge	do	Apr. —, 1886		21	3	7	4	108	7,000
Louisiana (North)	Calhoun	do	May —, 1887							
Maine	Orono	W. J. Morse	Mar. —, 1885	Oct. 1, 1887	14			11	417	20,000
Maryland	College Park	H. J. Patterson	—, 1888	Apr. —, 1888	37	21	1	13	318	32,700
Massachusetts	Amherst	S. B. Haskell	—, 1882	Mar. 2, 1888	51	19		23	212	16,000
Michigan	East Lansing	R. S. Shaw		Feb. 26, 1888	80	27	6	33	1,518	41,978
Minnesota	University Farm, St. Paul.	W. C. Coffey	Mar. 7, 1885	—, 1888	124	81	67	18	1,013	12,500
Mississippi	Agricultural College	J. E. Ricks		Jan. 27, 1888	34	11	1	19	170	18,000
Missouri (College)	Columbia	F. B. Mumford		Jan. —, 1888	67	58		35	865	6,267
Missouri (Fruit)	Mountain Grove	F. W. Faurot	Feb. 1, 1900		4					
Montana	Bozeman	F. B. Linfield		July 1, 1893	34	16	6	23	410	6,000
Nebraska	Lincoln	E. A. Burnett	Dec. 16, 1884	June 13, 1887	40	16		14	539	9,181
Nevada	Reno	S. B. Doten		Dec. —, 1887	9	2		1	16	8,000
New Hampshire	Durham	J. C. Kendall	—, 1886	Aug. 4, 1887	26	19	19	7	194	8,300
New Jersey (State)	New Brunswick	J. G. Lipman	Mar. 10, 1880		65	31	28	87	2,434	15,700
New Jersey (college)	do	do		Apr. 26, 1888	14					

New Mexico	Agricultural College	Fabian Garcia		Dec. 14, 1889	18	13	2	21	333	9,000
New York (State)	Geneva	R. W. Thatcher	Mar. —, 1882		50			35	969	18,000
New York (Cornell)	Ithaca	do	—— —, 1879	Apr. —, 1888	87	65	32	15	905	59,547
North Carolina	West Raleigh	B. W. Kilgore	Mar. 12, 1877	Mar. 7, 1887	45	9	45	7	276	12,620
North Dakota	Agricultural College	P. F. Trowbridge		Mar. —, 1890	51	12	22	16	482	8,600
Ohio	Wooster	C. G. Williams	Apr. 25, 1882	Apr. 2, 1888	72			33	1,526	70,490
Oklahoma	Stillwater	C. F. Dowell		Dec. 25, 1890	27	21		3	28	17,000
Oregon	Corvallis	J. T. Jardine		July —, 1888	55	30		15	347	1,550
Pennsylvania	State College	R. L. Watts		June 30, 1887	87	87	50	9	224	44.840
Pennsylvania (Nutrition)	do	E. B. Forbes	—— —, 1907		8					
Porto Rico	Mayaguez	D. W. May			9					
Rhode Island	Kingston	B. L. Hartwell		July 30, 1888	11	3		4	76	2,700
South Carolina	Clemson College	H. W. Barre		Jan. —, 1888	32	8	8	6	272	5,000
South Dakota	Brookings	J. W. Wilson		Mar. 13, 1887	17	17		8	152	16,000
Tennessee	Knoxville	C. A. Mooers	June 8, 1882	Aug. 4, 1887	23	2		11	242	12,500
Texas	College Station	B. Youngblood		Apr. 3, 1889	67	9		16	635	71,743
Utah	Logan	William Peterson		—— —, 1890	36	26	22	9	299	6,832
Vermont	Burlington	J. L. Hills	Nov. 24, 1886	Feb. 28, 1888	14	10	3	5	106	6,150
Virginia	Blacksburg	A. W. Drinkard, jr	—— —, 1888	—— —, 1891	31	8	3	10	242	12,000
Virgin Islands	St. Croix	J. B. Thompson			3			1	18	515
Washington	Pullman	E. C. Johnson		—— —, 1891	41	14		10	268	12.533
West Virginia	Morgantown	H. G. Knight		June 11, 1888	37	24	2	6	132	22,458
Wisconsin	Madison	H. L. Russell	—— —, 1883	—— —, 1887	96	78	62	22	729	56,877
Wyoming	Laramie	J. A. Hill		Mar. 1, 1891	22	13	7	5	204	7,100
Total					2,385	1,158	566	836	24,602	930,364

Revenues and additions to equipment, 1924

	Federal		State	Balances[1] from previous year	Fees	Sales	Miscellaneous	Total	Additions to equipment						
	Hatch	Adams							Buildings	Library	Apparatus	Farm implements	Live-stock	Miscellaneous	Total
Alabama	$15,000.00	$15,000.00	$34,500.00	$6,054.58		$16,696.57		$87,251.15	$232.53	$482.59	$1,702.81	$1,498.49	$667.05	$1,115.75	$5,699.22
Alaska[2]							$70,000.00	70,000.00	3,806.72			749.98	75.00	464.49	5,096.19
Arizona	15,000.00	15,000.00	93,305.06	1,287.88		1,613.54		126,206.48	2,728.11	205.50	479.48	1,890.59		1,444.87	6,748.55
Arkansas	15,000.00	15,000.00	50,703.37			15,676.94		96,380.31		950.00	3,249.73	3,501.41	159.96	956.99	8,818.09
California	15,000.00	15,000.00	434,539.92	26,336.43	$9,223.11	102,622.81	16,662.87	619,385.14	44,638.63	4,112.58	5,311.87	9,993.99	1,360.85	3,147.70	68,565.62
Colorado	15,000.00	15,000.00	117,540.92	28,951.72		33,332.75		209,825.39	1,172.12	580.21	5,049.87	2,519.39	8,553.46	3,210.00	21,085.05
Connecticut (State)	7,500.00	7,500.00	88,858.34	226.08	11,000.00		8,048.73	123,133.15	4,802.58	785.75	175.73	4,930.77		443.19	11,138.02
Connecticut (Storrs)	7,500.00	7,500 00	33,004.50	2,098.70			15,085.24	65,188.44	800.00	500.00	1,000.00	200.00	1,000.00	500.00	4,000.00
Delaware	15,000.00	15,000.00	17,500.00	2,528.10		11,492.69		61,520.79		546.97	875.79	1,000.00	80.00	500.00	3,002.76
Florida[3]	15,000.00	15,000.00	91,000.00	20,317.18		9,377.61	8,690.26	159,385.05	12,414.01	1,867.49	2,607.92	3,469.99	914.59	3,280.72	24,554.72
Georgia	15,000.00	15,000.00	8,000.00	2,396.94		25,786.23		66,183.17	1,000.00	611.79	490.30	467.30	1,002.66		3,572.05
Guam[2]							15,000.00	15,000.00							
Hawaii[2]							50,000.00	50,000.00	103.10	270.93	234.05	296.86		69.94	974.88
Idaho	15,000.00	15,000.00	28,203.31	209.41				58,412.72		100.00	200.00	300.00	500.00		1,100.00
Illinois	15,000.00	15,000.00	368,158.87	27,141.13		61,629.50		486,929.50	319,167.19					34,265.09	353,432.28
Indiana	15,000.00	15,000.00	225,081.38	108,103.02	123,443.50	76,312.16	21,072.72	584,012.78	44,043.16	1,506.33	2,224.28	7,312.98	14,157.54	1,356.53	70,600.82
Iowa	15,000.00	15,000.00	250,000.00	32,569.13		36,531.95		349,101.08	225.00		1,945.61	1,731.73	418.00		4,320.34
Kansas	15,000.00	15,000.00	103,550.00	12,527.60		55,921.03		201,998.63	10,507.13	327.31	348.26	9,951.17	5,530.00	930.16	27,594.03
Kentucky	15,000.00	15,000.00	68,000.00	45,243.79	99,158.43	41,144.40	5,000.00	288,546.62		1,019.33	365.90	405.50	2,949.20	453.31	5,193.24
Louisiana	15,000.00	15,000.00	40,000.00	3,975.87	34,157.23	7,264.00	6,193.42	121,590.52	2,125.86	672.46	1,153.99	2,524.23	1,547.38	517.86	8,541.78
Maine	15,000.00	15,000.00	25,000.00		11,886.07	15,420.18		82,306.25	1,366.42	705.81	456.74	2,872.33	68.00	1,670.16	7,139.46
Maryland	15,000.00	15,000.00	86,943.72			16,837.37	11,409.25	145,190.34	5,848.05	307.18	3,891.40	1,693.86	1,432.00	4,820.19	17,992.68
Massachusetts	15,000.00	15,000.00	124,359.87		40,733.93	9,710.88	393.54	205,198.22	7,571.10	1,163.99	633.40	2,264.09		767.36	12,399.94
Michigan	15,000.00	15,000.00	157,963.95			15,626.93		203,590.88	2,334.63	940.15	3,396.63	8,359.51	2,043.00	1,220.23	18,294.15
Minnesota	15,000.00	15,000.00	380,518.80			49,709.71		460,228.51	351,742.81	5,251.28	25,313.68	14,984.86	19,797.64	12,335.82	429,426.09
Mississippi	15,000.00	15,000.00	88,196.75	3,936.98		7,394.68		129,528.41	119,025.00	5,676.60	9,599.93	17,443.40	29,693.00	8,696.38	190,134.31
Missouri	15,000.00	15,000.00	67,108.55	35,322.76	28,698.16	57,618.41		218,747.88	310.30	58.77	3,044.59	247.23	2,274.04	3,646.19	9,581.12
Montana	15,000.00	15,000.00	107,598.62			27,479.06		165,077.68	2,500.00	150.00	700.00	3,500.00	800.00	750.00	8,400.00
Nebraska	15,000.00	15,000.00	123,301.00	22,759.10		40,899.12		216,959.22		271.48	4,139.76	5,263.30	16,105.72		25,780.26
Nevada	15,000.00	15,000.00	783.65	861.32		2,195.93		33,840.90	82.71	243.30	298.86	24.80	606.90	1,144.70	2,401.27
New Hampshire	15,000.00	15,000.00	7,000.00	986.70		2,081.70	14,724.91	54,793.31		425.49	1,453.15	30.00		433.55	2,342.19
New Jersey (College)	15,000.00	15,000.00						30,000.00	110,198.19	309.43	4,004.07	1,166.00	1,183.00	3,776.45	120,637.14
New Jersey (State)			167,500.00		52,029.42	24,324.12		243,853.54							
New Mexico	15,000.00	15,000.00	7,500.00	22,208.64		10,453.70		70,162.34	945.63	7.50	259.30	1,614.06	153.00	2,750.00	5,729.49
New York (Cornell)	13,500.00	13,500.00	239,130.65			34,398.47	266.38	300,795.50	12,720.40	1,218.36	10,558.97	3,038.93	196.01	1,757.16	29,489.83

New York (State)	1,500.00	1,500.00	247,451.12	----------	----------	3,312.17	----------	253,763.29	3,280.00	825.00	3,800.00	1,200.00	----------	1,700.00	10,805.00
North Carolina	15,000.00	15,000.00	149,161.99	1,497.17	----------	46,030.67	----------	226,689.83	13,255.29	567.24	1,448.57	3,623.25	2,437.95	3,156.86	24,489.16
North Dakota	15,000.00	15,000.00	296,516.68	40,469.85	----------	65,995.02	9,508.42	442,489.97	6,000.00	250.00	1,000.00	800.00	2,500.00	6,350.00	16,900.00
Ohio	15,000.00	15,000.00	597,575.00	13,301.73	----------	55,875.23	673.30	697,425.26	27,433.41	439.27	3,135.33	9,226.74	9,507.30	----------	49,742.05
Oklahoma [4]	15,000.00	15,000.00	12,500.00	----------	----------	6,679.26	----------	49,179.26	60,000.00	140.88	1,318.32	1,554.00	7,500.00	2,874.21	73,387.41
Oregon	15,000.00	15,000.00	99,500.00	55,337.22	----------	----------	32,161.82	216,999.04	3,844.30	473.23	1,324.72	1,656.71	6,339.09	5,000.00	18,638.05
Pennsylvania	15,000.00	15,000.00	62,225.12	----------	----------	18,636.43	----------	110,861.55	----------	815.10	4,306.12	2,208.74	4,214.02	----------	11,543.98
Porto Rico [2]	----------	----------	----------	----------	----------	----------	50,000.00	50,000.00	----------	----------	----------	----------	----------	----------	----------
Rhode Island	15,000.00	15,000.00	3,087.27	2,885.14	----------	7,578.88	----------	43,551.29	56.37	345.35	8.00	65.07	75.00	182.62	732.41
South Carolina	15,000.00	15,000.00	70,777.60	1,928.71	----------	35,989.24	----------	138,695.55	358.00	661.32	239.45	2,548.14	400.00	1,068.68	5,275.59
South Dakota	15,000.00	15,000.00	35,420.00	5,547.02	----------	9,345.00	3,132.18	83,444.20	----------	----------	1,050.00	400.00	----------	----------	1,450.00
Tennessee	15,000.00	15,000.00	41,949.52	----------	----------	13,633.69	----------	85,583.21	----------	473.36	135.45	2,710.53	----------	304.90	3,624.24
Texas	15,000.00	15,000.00	294,000.00	12,823.23	----------	78,124.43	----------	414,947.66	75,520.72	292.71	4,730.42	13,479.76	4,015.58	254.80	98,293.99
Utah	15,000.00	15,000.00	46,904.73	562.83	----------	9,322.41	1,000.00	87,789.97	1,600.00	600.00	400.00	400.00	300.00	100.00	3,400.00
Vermont	15,000.00	15,000.00	5,000.00	586.97	9,741.93	517.80	----------	45,846.70	1,841.06	187.19	2,479.44	262.12	740.50	----------	5,510.31
Virginia	15,000.00	15,000.00	64,912.50	11,362.68	----------	8,732.08	631.53	115,638.79	2,971.28	656.53	844.45	2,526.45	500.00	----------	7,498.71
Virgin Islands [2]	----------	----------	----------	----------	----------	----------	20,000.00	20,000.00	2,133.31	29.95	----------	291.17	126.56	----------	2,580.99
Washington	15,000.00	15,000 00	107,030.78	17,268.72	----------	51,987.20	----------	206,286.70	7,403.03	470.65	509.51	2,397.22	1,190.55	579.00	12,549.96
West Virginia	15,000.00	15,000.00	90,000.00	4,451.46	----------	27,254.55	----------	151,706.01	75,000.00	608.98	2,681.15	6,950.00	2,302.00	1,000.00	88,542.13
Wisconsin	15,000.00	15,000.00	243,663.66	----------	----------	67,944.30	9,740.85	351,348.81	27,000.00	2,581.99	5,545.36	3,932.87	3,709.48	3,103.76	45,873.46
Wyoming	15,000.00	15,000.00	12,500.00	1,674.48	----------	2,329.09	----------	46,503.57	11,530.33	1,861.44	2,906.95	475.75	2,388.50	----------	19,162.97
Total	720,000.00	720,000.00	6,115,027.20	575,740.27	420,071.78	1,318,839.89	369,395.42	10,239,074.56	1,381,638.48	43,548.77	133,029.31	171,955.27	161,514.53	122,099.62	2,013,785.98

[1] Not including balances from Federal funds.
[2] Supported by direct appropriations to the United States Department of Agriculture.
[3] Including a balance of 1 cent on the Hatch fund.
[4] Balances on Federal funds refunded to the Treasury. See pp. 111, 113.

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$9,484.08	$1,940.70	$508.79	$473.04	$66.79		$238.11
Arizona	15,000.00	14,048.95	146.40		53.00			3.75
Arkansas	15,000.00	8,280.00	1,906.57	1,512.98	352.21	157.78	$111.33	115.94
California	15,000.00	15,000.00						
Colorado	15,000.00	13,894.25	102.64	2.32	49.76			140.99
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	9,716.56	780.81	1,848.04	643.39	18.10	92.65	584.20
Florida [1]	15,000.00	15,000.00						
Georgia	15,000.00	9,042.33	3,054.15	289.00	459.80	375.98	609.95	36.18
Idaho	15,000.00	11,398.24	1,514.66		61.75	7.21	51.03	244.05
Illinois	15,000.00	15,000.00						
Indiana	15,000.00	14,846.23	149.76		.74			
Iowa	15,000.00	8,415.00	864.12	1,337.10	134.20	54.33	39.69	12.59
Kansas	15,000.00	9,700.00	4,427.22	6.28	99.31			255.61
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	6,873.32	3,744.41	315.00	262.62	96.87	466.56	32.00
Maine	15,000.00	7,516.07	3,649.48	271.00	357.34	143.93	765.55	95.28
Maryland	15,000.00	14,864.71	45.29					
Massachusetts	15,000.00	15,000.00						
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,744.96	3,174.18		27.40	159.47	190.13	
Missouri	15,000.00	7,218.93	3,674.83	7.35	181.01	164.23	63.84	272.70
Montana	15,000.00	14,780.00		195.93	6.07			18.00
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	10,075.17	2,306.62		249.37	47.30	84.41	
New Hampshire	15,000.00	10,590.43	430.10	699.96	404.41	278.71	600.00	252.10
New Jersey	15,000.00	11,130.82	670.28	187.36	218.66	8.20	208.19	236.21
New Mexico	15,000.00	7,483.49	2,608.28	1,723.12	132.22	94.29	205.74	136.03
New York (Cornell)	13,500.00	5,840.00	4,526.36		25.06	97.88	96.39	203.44
New York (State)	1,500.00	300.00	1,200.00					
North Carolina	15,000.00	12,415.59	1,882.00		203.64	26.31	347.86	124.60
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	6,783.34	3,151.92		181.95	340.23	1,083.00	25.85
Oklahoma	15,000.00	6,577.50	1,593.69	710.13	144.87	30.37	33.12	676.80
Oregon	15,000.00	10,270.50	2,661.32	852.14	29.19	17.88		64.16
Pennsylvaa	15,000.00	11,799.95	666.19	1,806.76	1.04	30.26		7.89
Rhode Island	15,000.00	5,627.96	4,777.76	1,080.49	144.26	452.91	319.60	.82
South Carolina	15,000.00	8,596.04	1,736.52	652.76	579.19	142.51	12.89	20.20
South Dakota	15,000.00	8,594.93	1,590.71	2,142.51	230.37	27.31		106.74
Tennessee	15,000.00	10,853.34	1,772.49	459.94	304.48	69.23	728.79	66.91
Texas	15,000.00	11,632.88	100.00		231.56			
Utah	15,000.00	10,700.00	1,677.79		42.80	139.58		56.56
Vermont	15,000.00	7,098.92	2,257.57	895.00	250.15	63.32	948.26	127.84
Virginia	15,000.00	10,607.07	3,246.52	12.58	191.61	54.22	46.38	15.53
Washington	15,000.00	10,154.82	2,185.08	1,109.26	43.26	26.83		
West Virginia	15,000.00	9,035.37	2,166.25	182.44	34.36	10.63		257.97
Wisconsin	15,000.00	10,050.00	1,868.51	633.67		6.21		959.91
Wyoming	15,000.00	6,745.00	4,529.87	291.17	1.04		49.52	292.19
Total	720,000.00	522,786.75	78,781.05	19,733.08	6,805.13	3,208.87	7,154.88	5,681.15

[1] Including unexpended balance of 1 cent.

act of March 2, 1887 (Hatch Act), for the year ended June 30, 1924

Classified expenditures—Continued											
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
$181.89	$244.03	$403.08	$305.39	$293.31	$334.09	$246.82	$1.80	$45.55		$232.53	
29.15		124.01	201.00					393.74			
897.01	257.10	550.77	100.18	121.70	401.74	70.92	88.00	29.27		46.50	
125.37		44.79	8.83	6.00	21.25	387.93		111.04		104.83	
129.10	18.00		268.07	102.04	47.97	236.52		491.13	$23.42		
377.90	405.21		48.87	213.39	10.85			76.39			
189.43		1,110.79	4.75	1.50			42.00	374.59			
3.27											
679.59	43.75	3,321.56		98.07							
103.30	87.63			120.00	20.18			180.47			
1,108.88	25.92	164.77	511.89	569.36	30.75			622.62	76.42	98.61	
142.98		1,316.62	319.41	41.86	17.42	75.00		280.88		7.18	
						90.00					
849.94	195.21	300.60		262.92				95.19			
588.49	20.50	2,130.72	24.00	225.75	52.11	258.60	47.60	69.34			
173.91		72.15	245.50	223.78	547.05	2.94	241.50	629.24		101.06	
180.31	73.55		342.85	94.05	159.70	490.16		363.15		40.52	
225.43	52.50	360.00		349.38	27.60	51.00		1,268.61	4.06	1.70	
267.24	150.30	484.97		721.23	19.65		153.00	398.02		422.42	
481.30	506.18			476.07	2.35	772.20		337.05	4.21	131.51	
192.65	737.00	1,498.96		787.23		217.87					
1,029.55	62.30	798.50	106.13	740.48	656.22	500.30		1,016.92		172.25	$[2]150.87
183.79		104.65	10.00	9.90				796.47			
403.20	7.50			16.22		2.50		258.49			
280.83	1,089.59	496.43	140.10	128.44	49.25			145.43	28.88	237.26	
482.62	416.37	1,037.03	701.06	201.59	226.80	58.83		115.78		19.80	
474.38	16.00	41.40	137.90	353.53	681.15	421.57		173.50	8.00		
80.51	57.00		321.06	29.35	43.67	37.58		86.57	1.49	87.59	
207.00				1,215.51	818.95	73.22				720.88	
263.01		1,256.40	19.89	166.29	24.30	157.15		448.95		47.28	
488.44	140.17		184.19	187.92	57.75	561.56	700.00	431.48		607.43	
391.79	67.51	1.35	106.99	62.57	38.45			24.65	20.00	112.78	
199.76			15.08	236.36				1,029.55			
733.66	184.19	260.07		516.33		675.19		943.54			
284.98	43.80			153.20		966.58		33.14			
		3,000.00		3.70		50.25		37.26			
12,430.66	4,901.31	18,879.62	4,123.14	8,729.03	4,289.25	6,404.69	1,273.90	11,308.01	166.48	3,192.13	150.87

[2] Refunded to the Treasury.

Expenditures from United States appropriations received under the

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000.00	$11,055.51	$802.87	$71.29	$150.41	$269.56	$834.84	$145.52
Arizona	15,000.00	12,468.26	404.55	98.26	75.66		360.02	170.60
Arkansas	15,000.00	9,430.70	2,455.73	22.36	76.11	63.05	788.37	151.10
California	15,000.00	12,254.06	915.56	106.58	2.50	49.26	419.28	309.75
Colorado	15,000.00	13,994.33	51.90				142.75	22.40
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	12,117.56	539.25	26.31	33.26		772.79	458.66
Florida	15,000.00	15,000.00						
Georgia	15,000.00	11,198.52	8.00	133.27	114.19	580.90	303.74	57.63
Idaho	15,000.00	11,135.05	1,450.13	14.48	53.27	52.80	1,137.95	214.32
Illinois	15,000.00	13,259.82	1,740.18					
Indiana	15,000.00	11,789.72	519.11	71.49			609.01	226.02
Iowa	15,000.00	9,395.00	2,575.20	35.54	13.78	114.71	1,069.48	527.44
Kansas	15,000.00	10,300.00	3,417.44	29.69	8.05		223.58	98.70
Kentucky	15,000.00	15,000.00						
Louisiana	15,000.00	12,150.00	805.65	1.92	32.02	264.75	608.19	99.42
Maine	15,000.00	15,000.00						
Maryland	15,000.00	13,876.49	140.00	8.79		38.02	449.80	
Massachusetts	15,000.00	15,000.00						
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	10,996.80	2,549.10	2.00	69.20	58.92	22.98	822.70
Missouri	15,000.00	5,118.83	2,614.21	51.22	296.06	398.28	1,319.34	350.91
Montana	15,000.00	10,733.62	2,447.82	5.80	47.65		215.02	225.14
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	8,154.30	2,899.08	22.32	99.45	229.54	437.79	225.98
New Hampshire	15,000.00	11,910.53	842.79	26.00	144.79		385.43	84.37
New Jersey	15,000.00	12,840.01	169.18	28.11	9.48	296.26	1,167.80	54.70
New Mexico	15,000.00	9,163.60	2,335.62	178.98	372.68	188.61	1,293.02	214.46
New York (Cornell)	13,500.00	11,086.13	1,011.52	9.19			333.20	358.63
New York (State)	1,500.00	1,500.00						
North Carolina	15,000.00	13,415.02	924.05		63.85		344.52	65.47
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	11,452.77	2,724.70	5.46			198.34	137.29
Oklahoma	15,000.00	10,280.00	800.63	30.15	44.33	11.43	752.54	535.80
Oregon	15,000.00	13,443.34	753.41	11.96	63.69	54.28	279.90	209.42
Pennsylvania	15,000.00	11,500.25	589.72	3.62	50.25	10.40	867.30	96.80
Rhode Island	15,000.00	9,634.27	2,513.98	.37	28.72	387.33	210.85	59.09
South Carolina	15,000.00	10,723.24	1,836.89	305.78	148.44	278.23	337.18	87.95
South Dakota	15,000.00	8,361.59	3,796.00	8.12	15.79		328.94	272.51
Tennessee	15,000.00	13,450.00	20.72	18.70	144.63	226.94	261.57	77.87
Texas	15,000.00	13,611.22	601.55	16.25		38.50	19.35	186.76
Utah	15,000.00	9,050.04	4,064.26	24.10	92.06		500.29	293.98
Vermont	15,000.00	8,180.18	2,776.66	95.75	46.46	66.84	242.75	190.21
Virginia	15,000.00	10,685.00	3,447.38	10.40	4.95	49.20	220.15	102.56
Washington	15,000.00	12,822.80	993.90	25.90	2.00		264.27	240.52
West Virginia	15,000.00	10,767.48	812.50				548.23	753.82
Wisconsin	15,000.00	8,850.00	3,370.95		1.82		503.49	76.51
Wyoming	15,000.00	12,830.32	580.08	7.48		40.00	303.35	72.26
Total	720,000.00	569,986.36	61,302.27	1,507.64	2,305.55	3,767.81	19,077.40	8,277.27

[1] Refunded to the Treasury.

act of March 16, 1906 (Adams Act), for the year ended June 30, 1924

Classified expenditures										
Fertilizers	Feeding stuffs	Library	Tools, implements and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and repairs	Balances
-------	$655.75	$96.62	$94.52	$17.75	$640.56	$149.62	$15.18	-------	-------	-------
$17.50	-------	4.50	13.86	-------	199.28	-------	881.12	-------	$306.39	-------
235.72	300.28	3.50	128.00	1.54	890.82	42.90	353.55	-------	56.27	-------
-------	274.89	28.55	14.70	140.31	151.64	128.22	204.70	-------	-------	-------
-------	5.97	9.91	-------	358.50	270.59	-------	143.65	-------	-------	-------
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27.00	-------	45.42	2.10	-------	639.27	-------	296.38	$7.00	35.00	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
74.00	1,428.86	26.76	10.00	-------	279.03	785.10	-------	-------	-------	-------
-------	30.42	-------	26.00	-------	160.65	-------	695.93	29.00	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
192.05	.40	42.00	178.23	1.45	384.71	797.40	188.41	-------	-------	-------
5.25	915.59	5.25	85.19	-------	103.32	-------	154.25	-------	-------	-------
-------	342.74	-------	37.45	53.43	6.21	239.00	115.53	-------	128.18	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
-------	133.60	62.95	39.25	49.00	719.64	-------	33.61	-------	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
-------	-------	9.70	8.00	28.09	423.61	-------	-------	-------	17.50	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
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-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
9.00	-------	46.63	-------	-------	326.62	-------	96.05	-------	-------	-------
4.70	2,160.06	6.00	204.86	136.61	1,969.05	106.65	148.87	3.90	110.45	-------
-------	-------	25.16	66.66	36.90	702.74	50.00	443.49	-------	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
-------	1,542.68	2.80	168.15	-------	44.72	338.00	835.19	-------	-------	-------
-------	372.14	-------	209.54	9.16	638.45	-------	48.31	-------	328.49	-------
-------	-------	-------	30.60	20.15	200.50	-------	-------	-------	183.21	-------
73.44	-------	7.50	682.26	23.80	259.30	120.00	-------	-------	86.73	-------
-------	-------	-------	19.97	36.50	644.86	-------	-------	-------	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
-------	-------	-------	-------	-------	110.43	-------	76.66	-------	-------	-------
-------	-------	-------	-------	-------	-------	-------	-------	-------	-------	-------
-------	179.37	-------	59.60	-------	242.47	-------	-------	-------	-------	-------
-------	724.76	-------	536.89	78.85	507.52	401.60	-------	-------	216.20	[1] $79.30
1.00	70.77	2.47	52.57	7.00	19.00	-------	17.19	-------	14.00	-------
40.80	72.26	190.26	40.25	9.15	1,406.88	-------	105.78	2.10	14.18	-------
-------	1,781.99	14.66	41.32	50.00	1.90	55.50	3.30	-------	216.72	-------
300.00	-------	108.72	208.18	19.20	646.19	-------	-------	-------	-------	-------
-------	60.43	1.80	461.61	318.45	1,054.16	115.00	160.06	-------	45.54	-------
-------	-------	28.62	247.92	23.65	215.95	-------	258.69	1.37	23.37	-------
-------	69.63	-------	200.37	51.20	5.00	-------	30.32	-------	169.85	-------
-------	-------	14.50	20.30	40.30	457.84	-------	364.31	-------	78.02	-------
28.50	620.89	-------	33.20	18.15	1,827.78	40.50	82.13	-------	750.00	-------
-------	110.50	-------	38.35	5.25	64.05	-------	125.50	-------	136.71	-------
12.00	-------	27.21	48.80	56.60	79.70	-------	426.30	-------	-------	-------
60.00	323.54	5.00	382.00	22.85	618.38	-------	706.20	-------	-------	-------
.60	1,889.14	-------	-------	-------	291.49	16.00	-------	-------	-------	-------
-------	956.04	-------	20.91	7.16	73.60	7.00	94.65	-------	7.15	-------
1,081.56	15,022.70	816.49	4,411.61	1,621.00	17,277.91	3,392.49	7,105.31	43.37	2,923.96	79.30

Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906

State or Territory	Hatch Act		Adams Act	
	1888–1923	1924	1906–1923	1924
Alabama	$538, 956. 42	$15, 000. 00	$236, 619. 89	$15, 000. 00
Arizona	504, 803. 10	15, 000. 00	239, 955. 61	15, 000. 00
Arkansas	538, 139. 12	15, 000. 00	239, 900. 00	15, 000. 00
California	540, 000. 00	15, 000. 00	239, 926. 84	15, 000. 00
Colorado	539, 718. 82	15, 000. 00	238, 638. 93	15, 000. 00
Connecticut	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Dakota Territory	56, 250. 00			
Delaware	538, 382. 87	15, 000. 00	235, 475. 12	15, 000. 00
Florida	539, 966. 05	14, 999. 99	239, 996. 06	15, 000. 00
Georgia	535, 593. 43	15, 000. 00	227, 092. 87	15, 000. 00
Idaho	464, 324. 13	15, 000. 00	235, 842. 22	15, 000. 00
Illinois	539, 564. 95	15, 000. 00	239, 851. 62	15, 000. 00
Indiana	539, 901. 19	15, 000. 00	240, 000. 00	15, 000. 00
Iowa	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Kansas	539, 995. 00	15, 000. 00	240, 000. 00	15, 000. 00
Kentucky	539, 996. 57	15, 000. 00	240, 000. 00	15, 000. 00
Louisiana	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Maine	539, 999. 62	15, 000. 00	240, 000. 00	15, 000. 00
Maryland	539, 967. 40	15, 000. 00	239, 236. 48	15, 000. 00
Massachusetts	539, 617. 70	15, 000. 00	240, 000. 00	15, 000. 00
Michigan	539, 676. 10	15, 000. 00	236, 341. 20	15, 000. 00
Minnesota	539, 917. 78	15, 000. 00	239, 345. 00	15, 000. 00
Mississippi	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Missouri	535, 097. 24	15, 000. 00	239, 999. 90	15, 000. 00
Montana	450, 000. 00	15, 000. 00	237, 417. 04	15, 000. 00
Nebraska	539, 932. 16	15, 000. 00	240, 000. 00	15, 000. 00
Nevada	539, 214. 32	15, 000. 00	238, 180. 28	15, 000. 00
New Hampshire	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
New Jersey	539, 949. 97	15, 000. 00	239, 392. 06	15, 000. 00
New Mexico	504, 509. 05	15, 000. 00	240, 000. 00	15, 000. 00
New York	539, 757. 18	15, 000. 00	239, 463. 01	15, 000. 00
North Carolina	540, 000. 00	15, 000. 00	225, 000. 00	15, 000. 00
North Dakota	481, 502. 26	15, 000. 00	239, 638. 85	15, 000. 00
Ohio	540, 000. 00	15, 000. 00	238, 514. 02	15, 000. 00
Oklahoma	464, 153. 03	14, 849. 13	219, 614. 49	14, 920. 70
Oregon	525, 156. 64	15, 000. 00	235, 000. 00	15, 000. 00
Pennsylvania	539, 967. 43	15, 000. 00	239, 995. 41	15, 000. 00
Rhode Island	540, 000. 00	15, 000. 00	237, 464. 20	15, 000. 00
South Carolina	539, 542. 15	15, 000. 00	238, 460. 12	15, 000. 00
South Dakota	483, 250. 00	15, 000. 00	235, 000. 00	15, 000. 00
Tennessee	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Texas	540, 000. 00	15, 000. 00	237, 592. 26	15, 000. 00
Utah	405, 000. 00	15, 000. 00	239, 821. 94	15, 000. 00
Vermont	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Virginia	537, 824. 12	15, 000. 00	239, 949. 01	15, 000. 00
Washington	477, 102. 65	15, 000. 00	236, 080. 11	15, 000. 00
West Virginia	539, 968. 71	15, 000. 00	237, 859. 12	15, 000. 00
Wisconsin	540, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Wyoming	525, 000. 00	15, 000. 00	240, 000. 00	15, 000. 00
Total	25, 301, 697. 16	719, 849. 12	11, 422, 663. 66	719, 920. 70

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UNITED STATES DEPARTMENT OF AGRICULTURE

OFFICE OF EXPERIMENT STATIONS

Washington, D. C. October, 1926

REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1925

By E. W. Allen, W. H. Beal, and E. R. Flint

CONTENTS

This report relates to the progress of the State agricultural experiment stations which participate in the Federal appropriations, for the year 1924–25. These appropriations are made under authority granted by the Hatch Act (March 2, 1887), establishing experiment stations in connection with the colleges of agriculture organized under the Morrill Land-Grant Act of 1862, and the Adams Act (March 16, 1906), increasing the support of these stations. The appropriations amount to $15,000 to each State under each of the above acts, or $30,000 annually, a total of $1,440,000. Reference is also made to the progress of the experiment stations in the outlying Territories and possessions, Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands, for which direct appropriation is made by Congress, the stations to be under the immediate charge of the Department of Agriculture.

This report, like those of previous years, is submitted in accordance with provisions of the Federal acts which clothe the Department of Agriculture with certain administrative, supervisory, and advisory functions in relation to the stations, exercised through the Office of Experiment Stations, and require "an annual report to Congress on the receipts and expenditures and work of the agricultural experiment stations in all of the States and Territories."

The year was one of continued progress, but without material change or enlargement, as the stations had, for the most part, reached the limits of their resources. It was, however, notable for two events of very large importance to the experiment station system, namely, the fiftieth anniversary of the establishment of the first experiment station in the United States, and the passage by Congress of legislation which will ultimately treble the Federal support of the State stations and materially broaden their field of investigation. It was a fact worthy of special note that just 50 years after the beginning of the experiment station as a State institution in this country, Congress should give such substantial recognition of the place it has attained in the Nation.

ANNIVERSARY OF THE FIRST AMERICAN STATION

The pioneer experiment station in this country was established in Connecticut in 1875. Agitation over a considerable period for an experiment station on the model of those existing in Europe resulted in the passage by the State assembly, in July of that year, of an act appropriating $2,800 per annum for this purpose for two years. The proposal aroused little interest on the part of the great mass of farmers, and this initial step was due rather to

friends of the measure who believed that if such a station could be established its usefulness would be so clearly demonstrated that it would be continued. Previous to that time there had been considerable investigation in the interest of agriculture in many of the States, notably at the agricultural colleges, and several of the latter had made some provision for it. The act of the Connecticut General Assembly provided for a definite, organized agency, which proved to be a permanent one, and has spread to the present national proportions.

While the growing use of commercial fertilizers and the need alike for their regulation and for a broader knowledge of the principles of their use were prominent motives in connection with the early stations, high ideals prevailed at the outset which did not permit their being developed as either exclusively control stations or left to the simpler forms of testing. The initial statement from the new station in Connecticut emphasized the absolute importance of abstract scientific investigation, and declared that "such an institution will be worthy of the name in proportion as it carries on thorough investigation and experiment in agricultural science." Two years later, when despite a severe financial depression the station was made permanent, the object of the appropriation was stated to be "to promote agriculture by scientific investigation and experiment."

This fiftieth anniversary was observed at the experiment station in New Haven, Conn., on October 12, 1925. The governor of the State presided and there were representatives from important agricultural and other organizations, the experiment stations of various States, and the Department of Agriculture, with greetings, congratulations, and appropriate addresses. The entire station system owes much to this initial step in Connecticut. The fact that the end of this half century finds the stations well established, definite in their aims, and with high ideals for their activity, is due in no small measure to the start made at the outset and the care and foresight with which the foundations of the movement were laid.

THE PURNELL ACT

The other outstanding event of the year was the passage of the Purnell Act, on February 24, 1925. This act, providing for the more complete endowment of experiment stations, was the culmination of a movement which had been in progress for several years. The measure had the support of representative agricultural and business organizations throughout the land, as well as the Association of Land-Grant Colleges, which had presented the needs and the advantages to agriculture generally of enlarged support for research. The sentiment in favor of such additional Federal aid was crystalized in the President's Agricultural Conference, and had his indorsement.[1]

The Purnell Act authorizes an appropriation of $20,000 for the year ending June 30, 1926, with annual increments of $10,000 thereafter until the total amounts to $60,000 annually for each State. Under this authority the maximum would be reached in the fiscal year 1930. The act specifies that this money is to be used for paying "the necessary expenses of conducting investigations or making experiments bearing directly on the production, manufacture, preparation, use, distribution, and marketing of agricultural products and including such scientific researches as have for their purpose the establishment and maintenance of a permanent and efficient agricultural industry, and such economic and sociological investigations as have for their purpose the development and improvement of the rural home and rural life."

The new appropriations are applicable to the stations already established under the Hatch Act, and, like those under that act and the Adams Act, are not dependent on equivalent contributions from the States. The act extends the same supervision by the Secretary of Agriculture that has existed over previous appropriations for the stations. It therefore involves no new policy or administrative machinery, and no change on the part of the stations except an expansion of their activities.

The enactment of this law was a significant recognition of the value of the work of the stations to the Nation, all the more striking because of the definite policy of retrenchment to which the Federal Government was committed. It was not only a notable expression of appreciation of the past work of the stations and recognition of the need of expanding their activities, but it definitely provided for enlarging their activities in the newer and somewhat untried fields of agricultural economics, rural sociology, and home economics, which were properly demanding greater recognition and attention.

Appreciating the important departure the new act represents and the added responsibilities it placed upon the

[1] For history of the movement see Association of Land-Grant Colleges Proceedings, 1925, p. 63.

stations, a conference of representatives of the Association of Land-Grant Colleges and the Department of Agriculture was called at St. Louis, April 22, 1925, to consider policies and plans under it, and to bring into closer coordination and unity the investigations of the stations and the department. The Secretary of Agriculture, in an address before this conference, expressed the conviction that the act would mark a new epoch in the history of the experiment stations, and called attention to some of the conditions surrounding it. He referred to the fact that the act provides "for the more complete endowment and maintenance of agricultural experiment stations now established" and hence "attempts to build on top of what already exists. * * * Its primary purpose is to develop further investigation and experiment * * * of substantial character. It is a fact-finding, fact-interpreting measure.

"Tested methods of research should be applied to investigations which will yield the most useful results. Every effort should be made to avoid a type of superficial investigation which now has been outgrown. Problems of fundamental importance should be attacked by adequate methods and with full knowledge of other investigations in order to avoid wasteful duplication.

"In other words, what is most needed is thorougly constructive work. The new fund is not for the exploitation of what is known or for speculation based on personal opinion or inadequate data, but it is for sound investigation in the best sense, calling for men and women with breadth and penetration of vision and of demonstrated ability in the research field."

The Secretary pointed out also that the Purnell Act recognizes in a substantial way the importance of finding solutions for the economic and social problems of the farm, and that for the first time it gives ample authority for carrying on investigation in home economics. He also stated that "the Purnell Act is not to relieve the States of their obligations. It is not designed to transfer these obligations to the Federal Government, but to enable the latter to join more liberally with the States in the maintenance of investigation at these institutions. * * * In advocating this latest legislation much emphasis was laid on what the States are now doing, and on the fact that it was not designed to relieve them but rather to stimulate and further extend their efforts. It is the confident expectation, therefore, that the individual States will continue to bear their part."

With reference to the organization of the new work, the expectation was expressed that the projects and methods would show at the outset a definiteness of purpose and a clear conception of requirements, and owing to the limitations of the first year's appropriation it was advised that only a few new projects be started. Referring to the tendency to attempt too many diverse studies at a time, the Secretary said: "It will be well if we can say that the funds available through the first appropriation were not spread out over too many undertakings."

Special emphasis was laid on the importance of cooperation and coordination within the stations, between stations, and with the department and other agencies. On this point Secretary Jardine said:

"It is a reasonable expectation that the Purnell Act will lead to a considerable enlargement of the cooperative relations between stations and with the various bureaus of the department. This seems important at the present juncture. It is in line with the idea of organizing investigation around problems instead of around a single station department. Very many of the problems we now face are too large for individual States acting separately. They are regional or even national, and there is danger of viewing them too narrowly. An experiment station working single handed can rarely expect to reach conclusive and comprehensive results in such broad subjects. * * *

"There is already a large and constantly increasing amount of cooperation between different bureaus of the department and the stations in investigations of various kinds. It is believed that such cooperation will be even more desirable in the relatively new fields of agricultural economics, rural sociology, and home economics. Not only are the problems in these fields of wide range, but the available workers are relatively few, so that the utmost use should be made of them."

In line with these suggestions, the St. Louis conference adopted six major topics of national importance around which to organize cooperation, and provided special committees of specialists to formulate plans and procedure under each of them. These topics were:

(1) Marketing and distribution of farm products.

(2) The problem of surpluses.

(3) Vitamin content of food.

(4) Rural home management studies.

(5) Rural social organization and agencies essential to a permanent and effective agriculture.

(6) A study of the factors which influence the quality and palatability of meat.

The special committees charged with the definition and plans of procedure under these topics presented their reports before the close of the fiscal year, outlining with considerable definiteness a number of projects which were considered advisable under these several topics. These were distributed through the Office of Experiment Stations by the joint committee on projects and correlation of research, representing the Association of Land-Grant Colleges and the Department of Agriculture. In calling attention to these national problems the committee expressed the opinion that they afford "an unusual opportunity of concentrating the attack on specific topics in a coordinated way which should lead to definite advance with the minimum waste of effort," and that "the ultimate success of this enterprise depends upon the full cooperation of all agencies, including the experiment stations and the Department of Agriculture." The committee therefore urged that the fullest consideration should be given to these plans, and that the response should be such as to give substantial encouragement for the various undertakings. As a result a large number of the stations indicated their purpose to cooperate in investigations on one or more of the topics.

In addition, sectional committees were organized at the St. Louis conference to arrange for cooperation in the study of special problems pertaining to their regions. The procedure thus set in motion for cooperative investigation and for approaching large problems on a coordinated plan was one of the significant features of the beginning under this new legislation.

ADMINISTRATION OF THE NEW ACT

In preparation for carrying out the part assigned to the Department of Agriculture in the supervision of the Purnell Act, the following circular was issued:

UNITED STATES DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY

Washington, D. C., May 20, 1925.

Subject: *Administration of the Purnell Act*

TO THE DIRECTORS OF THE AGRICULTURAL EXPERIMENT STATIONS:

The administration of the Purnell Act, with which the Department of Agriculture is charged, will be guided by the following general principles:

The underlying purpose of the act is "the more complete endowment and maintenance of agricultural experiment stations," a fact which recognizes the existence of an experiment station in each State as a going concern with an organization, administrative machinery, buildings, lands, and other basic facilities for research. In view of this and since the States are making substantial contributions toward the support of the stations, it would seem that general and overhead expenses such as apply to administration and upkeep, the care of buildings and grounds, maintenance of the farm and livestock, and similar ordinary expenses, might readily be cared for without drawing upon the new fund. It is the expectation, therefore, that the demand on the Purnell fund for general overhead expenses of the station will be reduced to the minimum.

The new act is designed to add to and strenghen the work of investigation; it directs that the funds appropriated in accordance with it "shall be applied only to paying the necessary expenses of conducting investigations or making experiments [in lines which are defined,] and for printing and disseminating the results of said researches." It is important, therefore, that the fund should represent definite pieces of investigation of substantial character, such as is called for in the present stage of agricultural inquiry.

With this idea in view, it will be expected that expenditures from the Purnell fund will be limited to those incurred primarily for specific investigations, with such charges for publication and for special buildings and lands as pertain directly thereto. The list need not be wholly restricted to new projects, but may include existing ones which it is desired to strengthen.

This will enable the Purnell fund to be administered on the same general plan as that followed with the Adams fund, namely, on the basis of a program of specific projects and a budget for expenditures, these to be submitted annually in advance for consideration and discussion in order that a good understanding may be reached. It is the more important because of the provision for expansion of investigation in several comparatively new fields, and the possibility of applying the fund to existing projects in other lines. All projects supported partly or wholly from the Purnell fund should therefore be submitted in outline in advance for examinatiom and approval as to their suitability to the new appropriation.

Since an annual financial report on the Purnell fund is required under the act, it will not be possible to pool it with other funds, but a separate account upon it will be necessary, and the above plan will facilitate such an accounting. Where the support of projects is shared in by other funds, it should be possible to show quite definitely what the Purnell fund is being used for. As in the case of the Hatch and Adams funds, the account should be a current one, and should be supported by a set of vouchers readily available for examination on due notice. The classification will be on the same basis as for other funds, and the financial report will be rendered on the same blank with them.

The Office of Experiment Stations has been designated to represent this department in matters relating to the details of administration of this law, and will aid in the promotion of activities under this act in the same general way as it has heretofore in relation to the Hatch and Adams Acts. It will also be represented in negotiations for cooperation between the department and the experiment stations, and will maintain a file of such cooperative agreements.

Sincerely yours,

W. M. JARDINE
Secretary.

This circular was mailed in connection with a call by the Office of Experiment Stations for the program of operations under the act for the first year. In the latter it was explained that a separate statement regarding the program and budget for it was desired, that projects to be supported from the Purnell fund should be outlined as under

the Adams fund, with the assignment of funds, noting such projects as would be conducted cooperatively with other stations or with this department, and that it would simplify matters if the Purnell fund was not mixed more than was necessary with other funds in the support of projects.

With the prompt assent of all the States to the provisions of the Purnell Act, as called for by section 2 of the act, all of the States were certified to the Secretary of the Treasury as entitled to receive the benefits under it. Steps were immediately taken by the different stations to formulate at least tentative programs and budgets covering the first year's appropriation, and by the end of the year substantial progress had been made in agreeing upon acceptable lines of work. Subsequently detailed projects were submitted for approval, in accordance with the plan outlined in the above circular of the Secretary of Agriculture.

RESPONSE OF THE COLLEGES

The attitude of the agricultural colleges and experiment stations toward the Purnell Act was further expressed in the following items of policy later adopted by the station section and the executive body of the Association of Land-Grant Colleges at its 1925 convention: [1]

(1) This act is supplementary to the two previous ones for experiment stations. It is to build upon what already has been provided. It is for a going concern, and it is not designed to relieve the States of their financial obligations. It is for new investigation or putting new force into work already under way.

(2) As it is supplementary and for increasing investigation, general overhead charges, except such as relate to the support of definite projects, are not considered warranted. The purpose the fund is serving will stand out more clearly if its admixture with other funds in the support of projects is held down to the minimum. To scatter it unduly and in small amounts over projects supported mainly from other funds will increase the task of administration and may suggest that it is being dissipated.

(3) The Purnell Act is designed to promote sound investigation in accordance with modern conceptions of that term and the present status of knowledge. Progress at this stage calls for clear-cut, concrete proposals. This implies analysis of complex problems and the study of individual features by the most adequate means that research has disclosed, with the constant aim of strengthening methods and making inquiry more penetrating.

(4) Only a relatively small field in the several branches of a station can be covered at a given time. Hence the plan of concentrating on a few topics in each field and making the work comprehensive, through, and conclusive is highly important. Do a few things well rather than many things indifferently.

(5) A systematic, well-rounded research program promises more at this stage than a fortuitous, disconnected set of projects. It enables a more adequate attack on the selected topics and a better related whole.

(6) The problem is the natural unit in the organization of research on many-sided subjects. A relationship will thus be established between the research in production and that in economics, sociology, and the home as a basis for "the establishment and maintenance of a permanent and efficient agricultural industry."

(7) The importance of cooperation and coordination within the stations, between stations, and with other agencies is recognized as now so definitely indicated as to make it a leading principle of administration. It is emphasized by the new fields of economics and rural life into which the stations are expanding. The breadth of many problems and their similarity in different sections favors joint effort in place of unrelated action. It is logical that the Department of Agriculture and the experiment stations should work in close union, and every effort should be directed to that end.

(8) Effective research requires trained workers, with a sound background in science quite as much as in their specialties. The need for investigators with vision, initiative, and keen perception is imperative at the present stage. The securing of such qualifications will mean the maintaining of a high standard of requirements and making positions sufficiently attractive to warrant the necessary preparation.

(9) The experiment station is one of the primary features of the college. Responsibility for discharging its functions does not cease with its administrative officers but is reflected on the parent institution. Sympathetic recognition and support of the essentials for research, the type of workers required, and the adjustment of their duties are fundamental in meeting just expectations under the new act.

(10) The administration of an experiment station has become a large and exacting matter. It has assumed an importance it has never had before. It calls for breadth of understanding and critical judgment in research, coupled with organizing ability and a familiarity with the leading problems of agriculture. With the present growth in prospect, effective direction will call for time to study the whole situation—the needs of the State, the proposals submitted, the organization of joint efforts, and the maintenance of contacts with the progress of the work. Upon wise administration will depend in the first instance the effective use of the large appropriations for agricultural research.

This formulation of the attitude and policy which will govern the development of the stations at the present stage is strong evidence of the determination to make this new fund accomplish what its advocates had in mind. It gives a construction which will be helpful in guiding the department in its administration of the act.

FUNDS FOR STATION USE

The total amount of funds available to the experiment stations for the fiscal year ended June 30, 1925, was $10,581,975.87, or an increase in station resources over the preceding year of $342,901.31. Of the total income for the year $1,440,000 was derived from the Federal appropriations under the Hatch and Adams Acts and $238,280 from specific appropriations for the stations in Alaska and the insular possessions. The main support of the stations came from State appropriations, which amounted to $5,827,871.88, and the remainder—$3,075,823.99—of the total revenues represents the bal-

[1] Association of Land-Grant Colleges Proceedings, 1925, pp. 182, 388.

ance carried over from the previous year and income from fees, sales, and miscellaneous sources. The total and summarized statement of the receipts and expenditures is given on page 154.

STATE CONTRIBUTIONS

For a considerable number of years there has been steady increase in the amount of money provided by the States for the support of the experiment stations. This, together with the provision of needed buildings and land and other facilities for carrying on investigation, has better prepared the stations for a broader field of operations. The volume of these State funds shows the background upon which the new Purnell fund was projected and the liberal manner in which the States are supplementing the Federal appropriations.

In the fiscal year 1925 the stations in the 48 States had for their use a total of $10,343,695. This was an increase of nearly $310,000 as compared with the preceding fiscal year. Of this amount $8,903,695 was from State sources. Direct State appropriations aggregated $5,827,871, balances brought forward from the preceding year amounted to $1,041,867, and the total from sales was $1,390,480. The remainder was derived from fees and miscellaneous sources. Totals by States are shown in Table 1:

TABLE 1.—*Income of the agricultural experiment stations from within the States for the year ended June 30, 1925*

States	State appropriations	Balances	Fees	Sales	Miscellaneous	Total
Alabama	$34,500.00	$16,048.56		$16,329.17		$66,877.73
Arizona	96,394.84	936.21		3,337.65		100,668.70
Arkansas	74,665.45			17,102.22	$1,400.00	93,167.67
California	507,937.93	34,553.67	$8,699.76	70,664.97	14,004.88	635,861.21
Colorado	122,132.53	33,639.28		24,317.24		180,089.05
Connecticut State	73,870.74	6,169.99	14,500.00		8,882.57	103,423.30
Connecticut Storrs	32,000.00	7,773.34			16,986.58	56,759.92
Delaware	17,500.00	2,301.29		14,407.00		34,208,29
Florida	87,500.00	24,104.90		9,989.91		121,594.81
Georgia	8,000.00	2,549.26		10,977.19		21,526.45
Idaho	26,794.59	460.02				27,254.61
Illinois	395,444.62	31.723.22		61,704.38		488,872.22
Indiana	226,160,07	114,280.44	145,070.36	100,217.64	22,022.44	607,750.95
Iowa	265,000.00	26,065.03		53,843.75		344,908.78
Kansas	100,400.00	18,645.06		78,165.80		197,210.86
Kentucky	113,000.00	31,190.86	99,432.44	42,911.24	5,000.00	291,534.54
Louisiana	40,000.00	8,624.26	30,626.05	17,075.95	1,786.18	98,112.44
Maine	25,000.00		11,816.40	15,528.96		52,345.36
Maryland	80,865.38			17,610.56	5,341.99	103,817.93
Massachusetts	134,193.17		39,977.05	14,392.81	132.93	188,695.96
Michigan	284,835.47					284,835.47
Minnesota	323,628.91			80,209.99		403,838.90
Mississippi	126,869.76	54,353.00		12.330.58		193,553.34
Missouri	71,148.88	43,823.00	28,145.46	37,665.89		180,783.23
Montana	110,727.53	4,096.19		19,285.02	282.74	134,391.48
Nebraska	128,519.10	8,151.17		51,771.82		188,442.09
Nevada	1,557.20	1,154.99		1,159.52		3,871.71
New Hampshire	7,000.00	3,472.96		2,189.56	14,863.93	27,526.45
New Jersey	129,230.73		49,219.11	29,020.71		207,470.55
New Mexico	7,500.00	21,811.26		8,000.00		37,311.26
New York Cornell	240,314.27			24,725.29		265,039.56
New York State	254,740.00			8,194.00		262,934.00
North Carolina	155,945.00	2,144.86		43,444.39	844.86	202,379.11
North Dakota		178,366.61		75,529.51	11,000.00	264,896.12
Ohio	405,675.00	348,073.20		50,041.19	2,375.05	706,164.44
Oklahoma	12,500.00	998.48		14,426.94		27,925.42
Oregon	104,500.00	52,454.98			27,932.75	184,887.73
Pennsylvania	60,408.80			10,906.90	11.236.24	82,551.94
Rhode Island	4,516.82	161.45		5,469.22		10,147.49
South Carolina	72,545.79	2,083.33		41,452.04		116,081.16
South Dakota	35,420.00	7,643.50		17,325.26	1,778.74	62,167.50
Tennessee	33,620.61			17,811.27		51,431.88
Texas	217,000.00	32,935.23		82,772.56	52,903.84	385,611.63
Utah	46,891.71	2,225.76		18,061.31	259.85	67,438.63
Vermont	12,560.78	65.38		1,000.41		13,626.57
Virginia	70,156.25	8,222.56		9,072.10	616.40	88,067.31
Washington	101,955.82			49,727.36		151,683.18
West Virginia	85,000.00	8,769.48		38,653.22		132,422.70
Wisconsin	249,244.13			70,773.61	16,337.20	336,354.94
Wyoming	12,500.00	1,794.93		884.37		15,179.30
Total	5,827,871.88	1,041,867.71	427,486.63	1,390,480.48	215,989.17	8,903,695.87
Federal funds						1,440,000.00
Total						10,343,695.87

As in the preceding year, all the stations received State aid in 1925, but in several instances the amount of State support was quite limited. The State appropriations of 12 stations remained without change, while those of 24 stations showed an increase and those of 14 a decrease. Only 4 stations—California, Ohio, Illinois, and Minnesota—mentioned in the order of decreasing amounts received, reported State appropriations amounting to more than $300,000. Seven stations receiving between $217,000 and $285,000 were Michigan, Iowa, New York State, Wisconsin, New York Cornell, Indiana, and Texas. The State appropriations of the following 11 stations ranged between $100,000 and $156,000—North Carolina, Massachusetts, New Jersey, Nebraska, Mississippi, Colorado, Kentucky, Montana, Oregon, Washington, and Kansas. Ten stations receiving between $60,000 and $97,000 were Arizona, Florida, West Virginia, Maryland, Arkansas, Connecticut State, South Carolina, Missouri, Virginia, and Pennsylvania. Eight stations—Utah, Louisiana, South Dakota, Alabama, Tennessee, Connecticut Storrs, Idaho, and Maine—received from $25,000 to $47,000, and 4 stations—Delaware, Vermont, Oklahoma, and Wyoming—received from $12,500 to $17,500. Five stations—Georgia, New Mexico, New Hampshire, Rhode Island, and Nevada—received less than $10,000 each. The North Dakota station reported no appropriation for this, the last year of the biennium for which State appropriations were made, but reported a balance of $178,366.61 carried over from the previous year.

As in previous years, the purposes for which the Federal funds were expended were ascertained for each station and the progress of the work as a whole, whether supported from these or other funds, was noted.

PERSONNEL OF THE STATIONS

There were 2,415 persons in the regular employ of the stations (not including laborers) during the year. This was a slight increase over the previous year. Of the total number of workers, over half, 1,265, took some part in the teaching in the colleges, their salaries being proportionately divided, and 347 assisted in the extension work. Of the total personnel, approximately half were independent workers or project leaders, the others being of the grade of assistants.

The station personnel has undergone a marked change, due to the character of the work and the demands upon it. In the earlier years, when the work was more elementary, the need for funds and for suitable facilities was to a large extent the limiting factor. Workers were adapted from the teaching force, and persons of limited experience or range of training could render acceptable service for the time. But with the change in the status of research the requirements for persons of sound training and experience have been increasingly felt. This has resulted in raising the standards for new recruits in most lines, and has stimulated large numbers of prospective station workers, or those already so engaged, to prepare themselves by advanced study and contacts with the methods of inquiry. While in some branches of the work this more severe preparation has lagged behind somewhat, the improvement in most branches has been very marked, and with the expansion now provided the demand for broadly trained investigators will be considerably increased.

The Purnell Act definitely broadens the field of research in the stations, and it was in these new fields of investigation that interest at first largely centered and in which there was the greatest immediate activity in the formulation of projects. In some of these lines the research field is only partially organized. One of the preliminary tasks has been to get better aquainted with the field, the points on which more detailed and fundamental information is needed, and the means of approaching the complex problems involved.

This has called for leaders, with vision and initiative, of which the number at the outset was not wholly adequate. The shortage has delayed some of the stations in embarking on these lines for the time being. This condition and the opportunity now open already are stimulating persons to prepare themselves for it and encouraging educational institutions to give special attention to the demand. In these newer fields, as well as in the better established ones, the measure of the research will be determined first of all by the corps of workers. They occupy the first place—funds and facilities are merely means of fostering their activities.

The campaign for new workers has naturally increased the competition among institutions to some extent and may result in considerable shifting, especially if opportunities are not adjusted. The situation has also made it

necessary to offer more liberal salaries in special cases, but the average for the most part is still not large.

A survey of the situation in the spring of 1925 showed that for persons ranked as department heads, leaders of separate lines, and independent workers, the salary ranges all the way from $2,400 to $6,000. Both of these extremes are, of course, exceptional. In three States the range was from $2,400 to $2,750, while for the larger proportion of the States it was from $3,000 to $4,500. In seven States the maximum salary paid workers of this rank was $3,500, and in half it did not exceed about $4,000, while in eight others it was within $4,500. In only nine States was the maximum for department heads or independent workers $5,000 or over. On the whole, it can not be claimed that the experiment stations are extravagant in the matter of salaries, and the probability is that in the more advanced positions and those calling for special training the amount will have to be increased.

CHANGES IN PERSONNEL

Although changes in personnel were numerous the turnover was less than for the previous year, indicating an encouraging degree of stability of the station staffs. The major changes during the year were as follows:

Changes in directorships.—L. E. Call was appointed director of the Kansas station and dean of the division of agriculture, succeeding F. D. Farrell, who had been elected president of the college upon the appointment of W. M. Jardine as Secretary of Agriculture. H. J. Patterson, director of the Maryland station, was made also dean of the college of agriculture. B. W. Kilgore, director of the North Carolina station, resigned, and was succeeded by R. Y. Winters, plant breeder of the station. H. L. Russell, director of the Wisconsin station, was granted leave of absence for study of the dairy industry of New Zealand, F. B. Morrison acting as director in his absence.

Other changes.—W. L. Blain was appointed associate plant pathologist at the Alabama station.

F. J. Crider, horticulturist at the Arizona station, resigned, and A. R. Kinnison was made acting head of the horticultural work and citriculturist. P. S. Burgess was appointed chemist at this station.

C. B. Hutchison, director of the Davis branch of the California College of Agriculture, resigned to take up work with the International Education Board. W. H. Boynton, formerly of the Philippine Bureau of Agriculture, was appointed veterinarian for the special study of hog cholera vaccines Appointments as associates in the station included I. J. Condit in subtropical horticulture, and F. Silvestre as entomological explorer, with headquarters at Hongkong, China. Jacob Traum, associate in veterinary science, was granted leave of absence for the study of foot-and-mouth disease in Europe.

L. W. Durrell was appointed botanist at the Colorado station, and J. C. Ward soil chemist at the Arkansas Valley substation.

P. J. Anderson, of the Connecticut State station, was placed in charge of the tobacco substation at Windsor.

P. B. Meyers succeeded L. W. Tarr as chemist at the Delaware station. A. E. Tomhave was transfered to the station as animal husbandman, vice T. A. Baker, who was transferred wholly to teaching. E. M. K. Lamkey, plant physiologist, resigned.

J. F. Cooper was appointed agricultural editor at the Florida station vice Ralph Stoutamire, resigned.

At the Idaho station, R. B. Gray, agricultural engineer, resigned and was succeeded by his associate, M. R. Lewis.

At the Illinois station, W. E. Carroll, of Utah, was appointed chief in swine husbandry, assuming his duties February 1. I. B. Boughton, assistant chief in animal pathology, resigned in April to take the directorship of the animal disease control work in Haiti. Robert Graham, who had been on a leave of absence in Haiti, returned to his duties as chief in animal pathology and hygiene at the station.

E. G. Proulx, who was connected with the chemical department of the Indiana station for some 15 years, died March 31, 1925.

At the Iowa station, E. S. Haber, assistant professor of horticulture in the college, was appointed assistant chief in truck crops vice W. C. Calvert, resigned. Wallace Park returned to his former position of assistant chief in apiculture, after an absence of two years at the University of Illinois.

At the Kansas station, R. I. Throckmorton succeeded Director Call as head of the department of agronomy. G. E. Johnson was appointed mammalogist and A. T. Perkins, research chemist.

P. H. Senn was appointed microscopist at the Kentucky station, and S. J. Lowry was made superintendent of the newly established substation at Princeton.

F. H. Leuschner was appointed associate poultry husbandman at the Maryland station.

C. H. Werkman, of Iowa, succeeded Arao Itano as research professor of microbiology at the Massachusetts station.

F. A. Spragg, research associate in crop breeding at the Michigan station, was killed in an automobile accident, August 11, 1924; and L. H. Cooledge, research associate in bacteriology, died May 12, 1925. C. G. Card was made acting head of the poultry department upon the resignation of E. C. Foreman. G. H. Coons, research associate in plant pathology, was granted leave of absence to conduct sugar investigations in the Office of Sugar Plant Investigations of this department. H. J. Stafseth, associate in bacteriology and specialist in diseases of poultry, was appointed exchange professor under the American-Hungarian Foundation, to spend a year in study at the University of Budapest. J. F. Cox, head of the farm crops department, was granted a four-months' leave for the purpose of serving the Federated Seed Service at Chicago.

At the Minnesota station, W. B. Combs was appointed dairy husbandman, and A. H. Johnson, biochemist, to carry on C. H. Bailey's work during his year's leave of absence.

C. J. Goodell was made associate animal husbandman at the Mississippi station, being transferred from the department of agricultural economics to this position. E. P. Brintnall, associate dairy husbandman, and H. D. Barker, associate plant pathologist, resigned.

H. R. Kraybill, chemist at the New Hampshire station, resigned and was succeeded by T. D. Phillips, of Ohio State University.

At the New Jersey stations, C. C. Hamilton succeeded Alvah Peterson as associate entomologist. W. C. Thompson, chief of the department of poultry husbandry, was given two years' leave of absence, beginning November 1, 1924, to serve as temporary director of the National Poultry Institute of England, established for advanced instruction and research.

R. F. Crawford succeeded R. L. Middlebrook as head of the department of biology at the New Mexico station. J. L. Lantow resumed his duties as animal husbandman July 1, 1924, after a year's leave of absence spent at the University of Illinois.

Appointments at the New York Cornell station included P. F. Sharp in dairy chemistry, E. F. Phillips in apiculture, H. E. Thomas in plant pathology, I. C. Hall in bacteriology, and J. N. Spaeth in forestry. J. R. Schramm, botanist, resigned to become editor-in-chief of the new International Biological Abstracts. R. A. Emerson, head of the department of plant breeding, was made also dean of the graduate school. W. M. Wilson, head of the department of meteorology, and T. J. McInerney, in dairy husbandry, were granted leaves of absence.

At the New York State station, D. C. Carpenter was appointed associate in research in chemistry.

H. L. Walster, agronomist at the North Dakota station, was made also dean of the school of agriculture.

A. Bonazzi, in charge of soil biological investigations at the Ohio station, resigned to become director of the Chaparra sugar cane experiment station at San Manuel, Cuba. M. A. Bachtell was appointed associate in farm management, to have charge of the three district and nine county farms. A. G. Newhall was appointed associate in plant pathology. Leave of absence for graduate work was granted R. C. Thomas, associate in plant pathology.

P. L. Menaul, chemist of the Oklahoma station, resigned and was succeeded by V. G. Heller, professor of chemistry in the college.

At the Pennsylvania station, C. D. Dahle was appointed associate in dairy manufactures. A division for storage research was established in the department of horticulture and L. M. Marble was placed in charge. F. D. Kern, head of the department of botany, was given a year's leave of absence, part of which time was to be spent as acting dean of the Porto Rico College of Agriculture at Mayaguez.

B. E. Gilbert was appointed chemist at the Rhode Island Station.

F. H. Lathrop was appointed entomologist at the South Carolina station to fill the vacancy caused by the resignation of A. F. Conradi. C. P. Blackwell, the station agronomist, resigned.

At the Texas station, Frank Grayson succeeded J. J. Hunt as wool and mohair grader. E. J. Wilson was made superintendent of the newly established substation in Wichita County. Upon the separation of dairy, swine, and poultry husbandry from the general lines of animal industry, G. R. Warren became chief of the divisions of dairy and swine husbandry, and R. M. Sherwood was made chief of the division of poultry husbandry. H. J. Reinhard, entomologist, who had been on leave of absence, resumed his duties May 1, 1925.

G. R. Hill, jr., botanist and plant pathologist at the Utah station, and dean of agriculture in the college, resigned, as did Gustav Wilster, associate in dairy manufactures. G. Q. Bateman was placed in charge of the Cronquist experimental dairy farm, and

J. W. Carlson was made superintendent of the experimental farm at Fort Duchesne, established for alfalfa seed work.

Ezra Brainerd, formerly president of Middlebury College and for several years associated with the Vermont station in botanical work on Rubus and Viola, died December 8, 1924.

At the Virginia station, C. E. Seitz, who resigned in the early spring, resumed his duties as agricultural engineer. R. A. Runnells was appointed associate animal pathologist. G. S. Ralston, field horticulturist, resigned. F. P. McWhorter was appointed associate horticulturist at the Truck station, Norfolk, vice R. J. Davis, resigned.

M. A. McCall, superintendent of the Lind, Wash., substation, resigned to come to the Bureau of Plant Industry of this department.

C. A. Lueder, veterinarian at the West Virginia station, resigned.

L. J. Cole, head of the department of genetics at the Wisconsin station, resumed his duties September 1, 1924, after a year's absence spent with the United States Department of Agriculture. Theodore Macklin was granted leave of absence to be spent in a study of the dairy industry of New Zealand.

ADDITIONS TO BUILDINGS AND EQUIPMENT

Substantial additions were made to the buildings and equipment of the stations during the year, largely, however, in the nature of minor improvements and special equipment for investigation. The total value of such additions was $1,475,201 as compared with $2,013,785 the previous year, classified as follows: Buildings, $782,789; farm implements, $136,887; livestock, $129,313; apparatus, $98,956; library, $35,379; miscellaneous, $291,876.

Some of the major features of improvements in buildings and equipment were as follows:

A State appropriation of $300,000 was made in Arkansas for the construction of a new building for the college of agriculture at the State University of Arkansas in which the station will share, and a grant of $10,000 was made for the establishment and maintenance of three substations for cotton, rice, and truck crops, respectively. Office facilities were provided at the station farm which were expected to be of material convenience in the experimental work.

The construction of a range of 10 greenhouses, each 30 by 80 feet, was begun at the California station. These houses were to be divided among 11 departments of the college of agriculture, with the larger proportion of the space allotted to pomology, plant nutrition, landscape gardening, and genetics. The funds for this purpose were supplied in part by the State and in part by private subscription. The construction of a stationary spray plant was begun at the university farm, the orchards being piped with mains connected with the stationary pumping plant.

The Florida Legislature provided for the erection of the first unit of a new agricultural building at the University of Florida to cost $125,000. This was to be used in part for station purposes.

A science building to be used partly for station purposes was completed at the University of Idaho at a cost of $400,000.

The installation at the Illinois station of a respiration apparatus sufficiently large to accommodate cattle and small horses, for the use of the division of animal nutrition, was undertaken. Metabolism crates for sheep and swine and a respiration apparatus for poultry were also provided.

A new experimental greenhouse costing $12,000 was completed at the Indiana station for use in experimental work in soils and crops and horticulture. The addition of this equipment also makes possible an expansion of the experimental work in pathology, physiology, and entomology. A house and laboratory costing $6,000 was completed for nutrition investigations and the breeding and care of small animals for this purpose. A hog barn was constructed at the livestock experimental farm at a cost of $5,500.

Contracts were let for a new home economics building at Iowa State College to cost about $600,000. This will afford better facilities for both college and station work. A new livestock judging pavilion 100 by 56 feet and costing $20,000 was under construction.

The biennial appropriations for the Kansas college and station carried among other items $10,000 for a sheep barn, $10,000 for new greenhouses, and $22,000 for additional land, partly for experimental purposes.

Approximately 400 acres of land near Princeton in Caldwell County was donated by citizens of the county for the use of the Western Kentucky substation, authorized by the State legislature in 1924, with an annual appropriation of $10,000. The same legislature also appropriated $25,000 annually for the establishment and maintenance of the Robinson substation at Quicksand in eastern Kentucky. This substation comprises about 15,000 acres of land and is to

give special attention to forestry investigations.

A sugar mill for experimental and instruction purposes was erected at the Louisiana station at a cost of $58,000.

A new $125,000 dairy and refrigerating plant was put into operation at the Maryland college and station. This is mainly for college and commercial purposes, but also to be used for experimental work.

A new wing was added to the home economics building of the University of Missouri, which it was expected would not only provide additional student facilities but furnish more adequate facilities for research in foods, nutrition, textiles, clothing, and home management.

The agronomy farm of the Nebraska station was enlarged by 175 acres, and a contract was let for a small cottage at the Valentine substation. Plans were made for a new dairy barn, sheds, and yards, as well as an open shed and beef cattle barn at the outlying farm.

Plans were made for a new plant industry building at the college of agriculture of Cornell University, which was expected to cost nearly $500,000.

The erection of an animal husbandry building with a State appropriation of $225,000, to be used partly for station purposes, was begun at North Carolina State College.

The Ohio station completed and occupied an agronomy building, to be known as Thorne Hall, with a State appropriation of $90,000.

The Utah Legislature appropriated funds for establishing two new experimental farms, one in San Juan County and the other in Uintah County. These farms were provided for the purpose of carrying on experimental work in the growing of alfalfa seed.

An appropriation was made by the State legislature for completion of the dairy manufactures building at the Washington station. Appropriation was also made for replacing the beef cattle barn.

STATION PROJECTS

The wide scope and variety of the work of the experiment stations is brought out by the classified list of projects active during 1924–25, which was prepared and distributed by the office during the year. This list shows 5,538 such projects for the State experiment stations and 150 for the experiment stations maintained by the department in Alaska and the insular possessions, making a total of 5,688, as compared with 5,420 the previous year. Of these, however, 54 are purely administrative and regulatory. Hence, the number of projects devoted strictly to research and experimentation was 5,634, or an average of more than 100 to the station.

The subject distribution of the projects differed little from that of the previous year. Field crops led with 1,817 projects, followed by horticulture 952 projects, animal production (including dairy cattle 191 and poultry 205) 926, plant pathology 482, entomology 472, soils 343, agricultural economics 235, fertilizers 213, veterinary medicine 203, agricultural engineering 189, botany 144, genetics 126, dairy products 106, forestry 100, foods and human nutrition 54, and various others.

There were increases during the year of 95 projects under field crops, 50 under entomology, 49 under agricultural engineering, 43 under soils, 33 under horticulture, 32 under plant pathology, 32 under poultry, 26 under economics, 25 under forestry, and small increases under various other snbjects.

Force of circumstances owing to demand for their services has led many of the experiment stations in the past to spread their funds and their resources over a larger number of inquiries than can be prosecuted intensively and energetically. The nature of the problems at the present time for the most part calls for intensive study. The requirements are not met by empirical experiments which only give comparisons applicable for the time and the conditions, and are not expressed in terms showing permanent relationships.

The real advances in agricultural practice and teaching have come from the application of knowledge and understanding, gained through close study and use of all that has been discovered by others, both as to facts and the light they throw on the real nature of the problem. Research attempts to build upon this foundation of information by making new contributions. It is needless to conduct more experiments unless they disclose something new or strengthen beliefs which need further confirmation.

Such procedure which aims at disclosing underlying facts and principles has become increasingly the objective in the investigations of the experiment stations. It recognizes the broad general background which has already been provided, and the fact that agricultural investigation, like all research, is a forward-looking effort, progressing on the basis of its own and related inquiries. Naturally it is a far more exacting type

of activity than the making of conventional experiments or following the routine of a long series of established trials. It calls, therefore, for concentration, the centering of effort on a few subjects, with close application to them.

With an undue increase in number of projects the tendency is for workers to scatter their efforts over too wide a field, not to go deep enough to get the basic facts, and not to put enough of themselves into the individual experiments to be constructive. Diffuseness is one of the evils that still needs to be guarded against.

The situation emphasizes the importance of the steps already taken to evaluate the projects under way and the promise they hold out to sift them critically and set high standards of performance to which they must conform. Unless they can justify themselves by their method and the evidence or prospect of progress, they are not in harmony with the present-day program of agricultural research. This is in accordance with the suggestion of the Secretary of Agriculture at the St. Louis conference, who said:

"The time also is opportune for taking stock of our present work, both in the Department of Agriculture and in the stations. Useless projects should be weeded out. Wasteful duplication should be stopped. The work in some lines of research may be broadened perhaps or better coordinated with other work. The purely scientific work can and should be better correlated with the economic work. Close scrutiny of its entire range of work by each of the stations, and closer cooperative relations between stations will be of far more importance to the future development of agriculture than any strict supervision which the Department of Agriculture might exercise."

WORK IN RURAL ECONOMICS AND SOCIOLOGY AND HOME ECONOMICS

A critical study of what might profitably be done to increase and strengthen investigation in rural economics and sociology and home economics as provided by the Purnell Act, has revealed a considerable diversity of opinion and practice in this respect, but strongly emphasizes the importance of a constructive purpose and definite objectives in all such work, as in other fields of research. There appears to be nothing to justify the setting up of standards of work in these fields essentially different from those accepted for other lines of investigation. Because the subjects have been less studied the work may necessarily be somewhat elementary in certain respects at the outset, but the aim will undoubtedly be to make the investigation of them purposeful, thorough, and progressive.

THE INSULAR EXPERIMENT STATIONS

There was substantial progress during the year in the work of the agricultural experiment stations maintained by the Department of Agriculture in Alaska, Hawaii, Porto Rico, Guam, and the Virgin islands, the work and expenditures of which are supervised by Walter H. Evans, chief of insular stations.

These stations were established and are maintained by the Federal Government primarily for the purpose of developing the agricultural possibilities of their respective territories in accordance with local needs and environmental conditions.

The experimental work in Alaska was carried on as in previous years at Sitka (headquarters) and Kodiak on the coast, and at Rampart, Fairbanks, and Matanuska in the interior. The work is done under widely varying conditions and is designed to establish such types of agricutural production as will supplement and aid in the development of other industries.

The experiment stations in Hawaii and Porto Rico are attempting to find profitable ways of diversifying the agriculture of those territories now centered largely on cane sugar production.

In Guam an effort is being made to improve the primitive methods of farming and to restore agriculture to its former important position.

In the Virgin Islands the effort is to show how diversified agriculture may improve the disturbed economic conditions and furnish profitable employment for many who formerly were otherwise employed.

The results of the work of the insular stations are published in detail in their reports, bulletins, and circulars.

The appropriations for the stations for the fiscal year ended June 30, 1925, were as follows: Alaska $69,500, Hawaii $53,000, Porto Rico $50,000, Guam $15,000 and Virgin Islands $22,500. In addition, $23,280 was appropriated to adjust the salaries of all the stations to make them as nearly as possible comparable with those in Washington, D. C., and a deficiency act of December 4, 1924, appropriated $8,000 for the control of the coconut scale in Guam, which had become a serious menace in the island.

CHANNELS OF PUBLICATION

The results of station work are published mainly through their regular series of reports, bulletins, and circulars, but to an increasing extent other channels of publication are being used and a wider and more varied dissemination of information secured.

The total number of regular publications issued by the stations during the year was 1,059, aggregating 26,537 pages and distributed to 853,732 addresses on mailing lists, in addition to those sent on special request. A classified list of these publications will be found on page 139.

Thirty articles prepared wholly by the experiment stations and nine others in which they collaborated were published in the Journal of Agricultural Research. Twenty-four stations were represented by one or more of such contributions. In addition, the stations contributed 1,305 articles relating to or based on their work to 290 other scientific and technical journals.

SOME RESULTS OF RECENT STATION WORK

The following classified review calls attention briefly to a few representative examples of contributions on a limited number of topics in the various fields of station work during the year covered by this report. It does not attempt a complete summary of all important current work of each station.

SOILS AND FERTILIZERS

Fully one-tenth of the recorded station projects deal with soils and fertilizers. The work covers a wide range and deals with many subjects of fundamental importance, especially with reference to crop and soil adaptation, use of fertilizers and other means of securing optimum conditions for crop production and maintaining soil fertility, and improvement of methods of tillage and soil management. The more generalized surveys and experiments are being supplemented to an increasing extent by specific studies of soil properties in their relation to fertility, productiveness, tillage, and crop adaptation.

Volume weight of soil.—Determinations of the volume weight of three types of soil by the Illinois station indicated that the present arbitrary values of 2,000,000 pounds for the surface 6⅔ inches, 4,000,000 pounds for the subsurface 6⅔ to 20 inches, and 6,000,000 pounds for the subsoil 20 to 40 inches are inaccurate in most cases. The average of three types of soil tested showed variations from 1,750,000 to 2,000,000 pounds for the surface 6⅔ inches, from 3,400,000 to 4,350,000 pounds for the next layer, and from 5,750,000 to 6,750,000 pounds for the 20 to 40 inch stratum.

Soil moisture and solution.—The soluble salt content of the soil was found by the Minnesota station to be correlated with the amount of water required for the production of dry matter in the plant. High osmotic concentration of the soil solution favored low water requirement in Atriplex and wheat.

The suction force of soils measured with the aid of a mercury manometer attached to a porous clay candle filled with water and inserted in the soil has been proposed by the New Jersey stations as a measure of capillary and molecular forces, with especial reference to the influence of soil colloids, the force of water absorption by roots of plants, and in obtaining soil solutions.

Soil moisture.—The California station has demonstrated the existence of two definite soil moisture capacities representing the minimum and maximum amounts of moisture retained by the soil when the water is applied at the surface and is free to move downward through the soil mass. This has an important bearing on cultural practice under irrigation, as well as under humid region conditions, particularly on the functioning of mulches and other means of moisture conservation.

Effect of mulches.—Soil mulch inhibited absorption of moisture in case of light rains by increasing evaporation, in investigations reported by the Washington station. When conditions especially favored evaporation, there was greater loss from mulched soils. Mulching, however, prevented loss of moisture already in the soil. Conditions may accentuate one or the other or nullify both.

Permeability.—All sodium compounds, except the acid salts of strong acids, were found by the New Mexico station to have a depressing effect on the permeability of soils, while the similar compounds of potash had comparatively little effect. Sodium carbonate had the most depressing effect. The salts of divalent metals did not depress the permeability. Some substances, such as aluminum sulphate, acid phosphate, manure, and salts with acid reaction, were found to improve the permeability. Ammonium sulphate was without immediate effect on permeability, sodium nitrate depressed it considerably, while acid phosphate improved it. Aluminum sulphate proved

not to be toxic in the soils studied and gives promise of becoming a satisfactory remedy for the treatment of impermeable areas which develop in irrigated lands. The Missouri station found that with liberal applications of rather insoluble salts, like calcium sulphate and carbonate, clay would remain flocculated for several years under ordinary conditions of leaching.

Colloids—Chemical analyses of colloidal clays derived from different kinds of soils, reported by the Missouri station, showed that such colloids are rather uniform in composition. Although the evidence obtained from a study of both soil colloids and synthetic mixtures of colloidal Al_2O_3, Fe_2O_3, and SiO_2 was not conclusive, "it would seem to indicate that many colloidal clays at least are composed largely of complex alumino-silicates rather than a mixture of the separate colloidal oxides. The chemical reactions of these alumino-silicates seem to follow the ordinary laws of chemical valence with the special condition that the reaction is restricted to the surface of the particles." The colloidal clays appear to act as weak acids.

Minor soil constituents.—Copper, manganese, and zinc, according to the Kentucky station, commonly occur in small amounts in fertile soils and in the plants grown on them and appear to play an essential part in plant growth and perhaps also in animal nutrition.

Aluminum toxicity.—The Rhode Island station found that the growth of more sensitive seedlings, such as beets and lettuce, was much depressed with 3.4 parts per million of alumina in the nutritive solution, whereas four times this concentration had only a slight effect on the growth of such plants as oats, corn, and cabbage, which are highly resistant to acid soil conditions in the field. The Hawaiian Sugar Planters' Station has shown that certain acid soils of low productive capacity for sugar cane contained soluble aluminum and iron and that the infertile condition may be attributed to aluminum toxicity, which is in a measure corrected by applications of potash salts and soluble phosphates.

Magnesium toxicity.—Hydrated silica was found by the Tennessee station to decrease the solubility of magnesium compounds in the soil and reduce their toxicity to tobacco.

Soil acidity.—The Rhode Island station observed that soil acidity conditions change with the crop grown. Alkaline crops, such as mangels and buckwheat, remove more alkaline than acid constituents and therefore tend to make a soil more acid, whereas carrots and millets remove more acid than alkaline constituents, leaving the soil less acid. The Iowa station found that acid phosphate lowered the hydrogen-ion concentration of the soil more than did ammonium sulphate and potassium chloride and that the acidity persisted for some time, especially in poorly buffered soil. In other soils the acidity quickly disappeared.

Buffer action.—The Delaware station found that different soil types of the State varied more in their "buffer" qualities than they did in pH values. Some of the soils were so poorly buffered that they were easily thrown out of proper balances for optimum crop conditions, while other soils were so highly buffered that but little change was made in their pH values by heavy additions of either acid or alkali. The buffer action of all soils tested decreased as the temperature increased. The Michigan station showed that the buffer action of acid soils toward acids and bases closely parallels the adsorption phenomena displayed by pure activated sugar charcoal, indicating that, in part at least, soil acidity is due to adsorption effects.

Replaceable bases.—When the replaceable base in heavy clay soils was potassium, the water-holding power of the soil was found by the Utah station to be greatly reduced, indicating that the very fine capillaries were reduced in size and number. Soils saturated with calcium showed the highest water-holding power, those saturated with sodium being intermediate in this respect. The conditions were reversed, however, with a high water content, in which case sodium-saturated soils held the largest amount of water and calcium-saturated soils the least.

From a beneficial standpoint replaceable calcium appeared to be the most important single element in soils, according to experiments reported by the Oregon station. From the standpoint of soil troubles, however, and especially under alkali conditions, replaceable sodium appeared to be the most important element. No relation between physical character of the soil experimented with and the amount of replaceable base was observed.

Alkali soils.—According to the California station alkali soils in general may be classed in three groups: (1) Those which contain high concentrations of soluble sodium salts and are low in soluble calcium salts, which soils have excessive amounts of replaceable sodium and require special treatment with gypsum, sulphur, or some similar material for their reclamation; (2) soils with high soluble sodium salts and considerable soluble calcium, which

contain an intermediate amount of replaceable sodium and may or may not require special treatment, depending upon their organic and calcium carbonate content; and (3) soils with high water-soluble calcium salts, which soils are merely in need of leaching and drainage. In the reclamation of all of these soils the drainage question is of primary importance. The station found that it is possible by laboratory methods, to determine the nature of the treatment required by a given alkali soil.

Effective correction of black alkali, sodium carbonate, by use of gypsum was reported by the Arizona station. The application of gypsum not only improved the drainage but effected an important saving of the plant food of the soil. The gypsum did not penetrate very deeply into the soil, but the crop results indicated that if an excess of gypsum is kept in the surface foot of the soil a considerable concentration of black alkali will be tolerated in the subsoil.

Organic matter.—The Washington station concludes from its investigations that in any system of agriculture (except where acid soils are brought under irrigation) it is impossible to maintain the soil organic matter content at the point at which it was found in the virgin state. There is a definite relationship between the organic nitrogen and carbon in the soil, and this relationship has a tendency to maintain itself under natural conditions, with the result that the effective organic matter in the soil can not be increased or even maintained unless the nitrogen is also increased or maintained. When organic matter is lost from the soil as a result of decomposition the carbon is lost more rapidly than the nitrogen and the remaining organic matter becomes more and more resistant to decay as its nitrogen content increases above the percentage present in the virgin state. Crop residues, like straw, which are low in nitrogen content have a depressing effect on nitrate accumulation and on yield when first applied, which is overcome only after the residue has decomposed to a point where enough carbon has been lost as carbon dioxide to bring the carbon-nitrogen ratio to about 11 to 1. Organic materials, when applied to the soil for the purpose of increasing the effective organic matter, are beneficial in proportion to their nitrogen content. Distribution of organic matter in the soil is influenced in a very pronounced degree by soil reaction. An alkaline soil solution tends to dissolve the organic matter and distribute it through a greater depth of soil, whereas an acid soil solution precipitates the organic matter and thus prevents it from leaching into the subsoil. A high organic matter content in soils checks erosion by opening up the soil so that the moisture of precipitation is absorbed as rapidly as it falls.

The maintenance of a practically constant carbon-nitrogen ratio (10 to 1) in soils is ascribed by the New Jersey stations to the action of microorganisms. A wider ratio appears to result in nitrogen starvation and waste of carbon, a narrower in liberation of ammonia, thus tending to maintain a constant ratio. It is found that under aerobic conditions fungi are largely concerned in the decomposition of cellulose in the soil. The rapidity of decomposition depends largely upon the amount of available nitrogen, there being a definite correlation between the amount of cellulose decomposed by the aerobic microorganisms and the amount of nitrogen changed from an available form into microbial protoplasm, the ratio being about 30 to 1. When straw or other organic material rich in cellulose and poor in nitrogen was added to the soil, it was decomposed only to the extent that the nitrogen became available in the soil; and there was thus a competition between the growing plants and the soil microorganisms for the available nitrogen, and the cultivated plants suffered. The addition of available nitrogen in the form of ammonium salts or nitrates tended to prevent the injurious effect of a large quantity of straw upon the newly planted crop. Under anaerobic conditions the celluloses were decomposed by bacteria, and the nitrogen required in this process was considerably less than under aerobic conditions. It was found that some organisms broke down natural proteins largely to amino acids, while others decomposed these with rapid formation of ammonia. The decomposition of protein in the soil was thus the result of the combined action of at least two microorganisms.

Effect of manure and straw.—The Utah station found that the application of manure tended to widen the carbon-nitrogen ratio of the soil. It also increased the loss of calcium and magnesium from the upper layers of the soil. Magnesium carbonate was rendered more soluble than calcium carbonate, and hence the calcium-magnesium ratio was widened. The New York State station found that straw extracts exerted a harmful effect on plants even after sterilization, indicating that the effect is at least partly chemical. Certain organic compounds were isolated

from the straw extract, which showed a toxic effect on seedlings.

Lime and liming.—Sixty-mesh and 100-mesh limestone was found by the Delaware station to be as effective as burnt lime in decomposing organic matter in the soil, as measured by the carbon dioxide evolved. No difference was observed in the effects of the treatment on bacterial number or availability of phosphorus and potash. Limestone coarser than one-twentieth inch had little effect during the first two years after application, and that coarser than one-tenth inch was comparatively ineffective for three or more years, in greenhouse experiments at the Illinois station.

Nitrogen level of soils.—The results of eight years' studies at the Missouri station indicate that under Missouri conditions the nitrogen level of the surface foot can not readily be maintained above 4,000 pounds per acre. It is believed that providing a large revolving fund of nitrogen from crop residues, manure, and green manure is more important than maintaining a definite nitrogen level.

Nitrogen fixation.—The nodule bacteria of soy beans and red clover in dry soils stored for seven years in the laboratory were found by the Missouri station to be no longer viable but survived in soils in the field, indicating that a soil once inoculated will retain the organisms to reinoculate the legume as it recurs in rotation.

Bacterial counts in the field by the Washington station showed that as long as the moisture was approximately optimum and maximum daily temperature remained around 20 to 25° C. the number of nodule bacteria was fairly constant at 10,000,000 to 30,000,000 per gram of soil; but as the temperature increased and the moisture decreased a gradual drop in bacterial numbers occurred. During a period of three months, in which the maximum daily temperature frequently reached 30° and the moisture was between 1 and 2 per cent, the count remained fairly constant at 500,000 to 1,000,000 per gram of soil, but the number rose again when the fall rains came and the daily temperature again approximated 20 to 25°, showing that drought and heat have only a temporary effect.

Nonsymbiotic fixation of nitrogen in soils was increased by inoculation with cultures of the nitrogen-fixing organisms *Azotobacter chroococcum*, *A. vinelandii*, and *A. beijerinckii* prepared and tested by the Iowa station. Satisfactory methods of preparing the inoculating cultures have not yet been worked out, and hence the method has not been put on a commercial and practical basis. It is suggested, however, that soil inoculation with Azotobacter may eventually become a profitable practice under actual field conditions. In the experiments here reported, inoculation with Azotobacter did not increase the yield of wheat, although there was an accumulation of nitrogen. The number of Azotobacter in the soil increased and decreased directly with the nitrates but generally inversely as the ammonia.

Ammonia and nitrate formation.—The power of soil microflora to produce ammonia from protein in acid reacting silty clay loam was found by the Oregon station to be little affected by the application of lime, plants capable of using ammonia thriving in these soils in proportion to the amount of decomposable nitrogenous organic matter. The production of nitrates from ammonia was greatly stimulated by moderate quantities of lime, indicating that plants requiring nitrates would be benefited by lime and probably would suffer from lack of nitrogen unless lime were added.

Nitrate production was comparatively slow, in experiments at the Nebraska station, at 5° C. and increased with the temperature, reaching its maximum at 35°, ceasing altogether at 55°. It was insignificant at moisture contents as low as the hygroscopic coefficient of the soil, but increased with the moisture content up to the highest point measured, one and one-fourth times the moisture equivalent.

From a study of the depressive effect of plant residues on the nitrate content of soil, the New York Cornell station reached the conclusion that this is due to stimulation by the plant residues of the action of soil organisms which assimilate and transform the nitrates into other forms of nitrogen. The rate of depression varied with the kind of plant material, being more prolonged with timothy residues than with clover residues, due to the greater ease and rapidity with which the latter is decomposed and assimilated by the organisms and their consequent more rapid multiplication and growth.

Many of the soils of Colorado contain nitrates in sufficient quantities to be injurious to crops. The station's investigations indicate that in many cases this nitrification is due to the combined action of vigorous nitrogen-fixing, ammonifying, and nitrifying organisms stimulated by high summer temperature, clean culture, abundant moisture, and a favorable soil reaction

of pH 7.4 to 7.6. The nitrogen-fixing organisms apparently derive their energy from soil algae, of which some 21 species have been identified. There is a greater accumulation of nitrate during the growing season under cultivated than under uncultivated crops. This unusual situation makes necessary the finding of means to restrain nitrification, and different crop rotations have been studied with this object in view. The application of either sulphur, acid phosphate, or green manures appears to improve the quality and yield of sugar beets on the high nitrate soils. On fallow land excessive formation of nitrate has been controlled by the use of sulphur.

Loss of nitrates by leaching.—Experiments reported by the Alabama station indicated that the loss of soluble nitrogenous fertilizer by leaching may be reduced by delaying the application until the crop will absorb it rapidly. Nitrate of soda applied to oats at the rate of 400 pounds per acre 42, 70, and 92 days after planting was found completely absorbed in 20, 14, and 10 days, respectively. Applied to cotton at the rate of 600 pounds per acre 14, 40, and 61 days after planting, the nitrate was absorbed in 36, 14, and 11 days, respectively.

Heavy additions of lime were found by the Tennessee station to be initially repressive of nitrate outgo in lysimeters, to the point of inhibition, but the residual effect was to produce a very heavy loss of nitrate nitrogen. Sulphur, either as ferrous sulphate, pyrite, or elementary sulphur, caused a depression in nitrate outgo. Very heavy additions of magnesium oxide proved less active than corresponding additions of calcium oxide in promoting nitrate losses.

Availability of nitrogenous fertilizers.—Experiments made by the New Jersey stations confirm the fact that plants use nitrogen very rapidly in the early stages of growth and emphasize the importance of having a supply of available nitrogen ready for the plant when it is starting to grow, especially in the early spring when nitrifying processes are slow. In the New Jersey experiments the average utilization of nitrogen by the plant was 62.6 per cent in case of nitrate of soda, 54.24 per cent in case of ammonium sulphate, 46.62 per cent in case of tankage, and 25.84 per cent in case of calcium cyanamide.

Sulphur.—Large applications of lime to the soil were found by the Tennessee station to practically inhibit outgo of sulphates in lysimeter leachings, but this effect was not permanent. The retention of sulphates in heavy limed soils is explained by the formation of the ternary systems $CaO–Fe_2O_3–CaSO_4$ and $CaO–Al_2O_3–CaSO_4$. The sulphur content of soils was found by the Illinois station to be correlated to some extent with that of organic matter. In the tests made the amounts of sulphur in the surface soil ranged from 100 pounds per acre in ordinary soils to several thousand pounds in certain peaty soils, averaging from less than one-half to three-fourths as much as phosphorus. Without the sulphur added by rain the soil supply would probably be inadequate for normal growth of crops.

Sulphur and gypsum increased the yield and nitrogen and sulphur content of alfalfa and clover in experiments at the Washington station. There were indications that the chief beneficial action of sulphur was to aid the nodule bacteria in supplying more combined nitrogen to the plant. The sulphur was most effective when applied as a top dressing. In a study of the effect of sulphur and gypsum on Palouse silt loam, this station found that the soil had a naturally high sulphofying power, and uninoculated sulphur was just as efficient as inoculated in producing sulphates. The gypsum and sulphur were readily leached out during the winter months. They also increased the availability of the soil potash under greenhouse conditions. Sulphur oxidizing in the soil increased the loss of soil calcium. Magnesium was but little affected by either sulphur or gypsum. Nitrification was but little affected by either. Sulphur applied to alfalfa gave no marked increase in yield or root development, in experiments at the Kansas station, indicating that sulphur is not the limiting factor in alfalfa production on the type of soil used. In general, the acidity of the soil was increased by the application of sulphur.

Application of inoculated sulphur increased soil acidity and resulted in brighter and cleaner potatoes, with a higher percentage of primes, in experiments at the Delaware station. There was also evidence that the sulphur treatment improved the keeping quality and retarded development of black rot and soil stain but not of Fusarium wilt.

Subsoil potash.—Pot experiments with millet grown on different layers of soil at the Massachusetts station indicated that the potash of the deeper subsoils is either more available or more abundant than that of shallower subsoils,

and in this case was sufficient for maximum production. The availability of the potash was measured by the percentage of potash in the crop.

Soil erosion.—The Missouri station found the erosion from soy bean land having a slope of 3.68 per cent to be 86 times as great as from sod land and 84 per cent as great as from land continuously in corn. Nitrogen was lost in the eroded soy bean soil at the rate of 32 pounds per acre annually.

Maintenance of fertility.—Thirty years' results of the carefully planned and executed field experiments of the Ohio station on maintenance of soil fertility have recently been summarized. The experiments were made at five different places on as many types of soil. The outstanding facts brought out are that acid phosphate is especially profitable as a fertilizer for wheat, that corn is more responsive to potash than wheat, that the use of nitrogenous fertilizers in a rotation containing a legume is not likely to be profitable, and that liming is largely and widely profitable under the conditions of these experiments.

Manure and crop residues.—The proportion of the fertilizing constituents in the feed recovered in the manure of dairy cows was found by the South Dakota station to vary decidedly. More potash and nitrogen was recovered in feces than in urine. The nitrogen, phosphoric acid, and potash recovered varied with the type or breed of the animal and with the daily milk production. In a very general way, the recovery of potash and nitrogen was in inverse relation to milk production, while the phosphorus recovery paralleled the production of milk.

In a comparison made by the South Dakota station of turning under all crop residues (cornstalks, oat straw, and clover hulm), in a rotation, with harvesting and feeding these residues and returning the equivalent in manure, higher yields were secured in the first year from the manure plats, but the yields of later years were higher from the plats where crop residues were turned under directly.

PLANT PHYSIOLOGY AND NUTRITION

Photoperiodism.—Extending to beans and sweet potatoes work of the same character as that previously done with *Tephrosia candida*, the Porto Rico station found, as in the case of Tephrosia, striking differences in growth with varying lengths of day. Investigations by the Minnesota station showed that when illumination was constant the growth rate was constant and indicated that the usual differences of growth by day and night were not caused by internal rhythm. The rate of growth and fluctuations in the supply of nutrients produced during the illumination period seemed to be related to the production of bloom and seed and was evidently due to the reaction of the plant to the length of day. Many plants apparently do not require a particular length of day for blooming.

Plant metabolism.—A study of the distribution and rôle of phloridzin in apple and pear tissue by the Oregon station showed the greatest quantity of phloridzin in such tissue in the early summer, the period of highest metabolic activity. At this period phloridzin may increase to 20 per cent of the total solids, or 5 to 6 per cent of the fresh weight of the tissue. It was found to be most abundant at the tip of the shoot and uniformly less toward the base. The general speculative conclusion is "that the phenol acids, upon which the synthesis of phloridzin depends, are a sort of by-product of metabolic activity, and that phloridzin serves as a protection against an accumulation of these substances or as a temporary repository of them for future use by the tissue. The possibility of a direct rôle of phloridzin as an accelerator of vital processse was indicated." An improved hydrolysis method of determining phloridzin is reported.

Plant colloids.—Potato tuber and other kinds of plant tissue were found by the Missouri station to act much like amphoteric colloids, with isoelectric points as follows: Potato-tuber tissue pH 6.4, soy bean root tips (variety Virginia) 6.2 to 6.44, the mycelium of *Gibberella saubinetii* 6.2, the mycelium of *Fusarium lycopersici* 5.5, and the mycelium of *F. oxysporum* 4.9.

Nitrogen fixation by nonleguminous plants.—That nonleguminous plants fix nitrogen through nodules on their roots is indicated by observations reported by the Michigan station on a number of nodule-bearing nonleguminous plants of that State, notably Ceanothus, nodule-bearing plants of which were found to contain more nitrogen than those free from nodules.

Nitrogen assimilation.—In experiments at the New Jersey stations it was found that in solutions containing both NO_3 ions and NH_4 ions, soy beans, in the early stages of growth, absorbed nitrogen in the form of NH_4 at a higher rate than in the form of NO_3. During the later stages of growth this was reversed. Corn in the very early stages of growth absorbed no measurable quantity of nitrogen in the form of the NO_3 ion, but obtained its nitrogen as NH_4 when both were present. In later stages both NO_3 and NH_4 ions were absorbed. The pres-

ence of an ammonium salt in the culture solution increased the nitrogen content of the plants over that of plants grown in a culture solution in which the nitrogen was present in the form of a nitrate in equivalent concentration of nitrogen; but this excess nitrogen in the plant did not affect the protein nitrogen content, which remained approximately constant, the excess nitrogen being in the nonprotein form. The stations also found that the high nitrogen content of the soy bean plant following the addition of calcium to soils or culture media bore no relation to the protein nitrogen, the increase being due to nonprotein nitrogen. A higher content of both nitrogen and calcium in the plant occurred in the presence of calcium carbonate than in the presence of nitrate or chloride. The higher nitrogen content of the plant was definitely correlated with relatively low hydrogen-ion concentrations.

Germination of wheat seedlings.—In the early stages of germination of wheat the ether extract was found by the Iowa station to disappear from the seed more slowly than the carbohydrates or proteins. The amount of sugar increasd rapidly during the first six days. After 12 days the plants appeared to be dependent upon photosynthetic activity. Wheat seedlings required relatively large amounts of mineral nutrients.

GENETICS

Station work in both plant and animal genetics showed an increase during the year. Over 125 genetics projects were recorded as in active operation at the stations during the year. A few examples of recent work in this field are briefly noted, as follows:

Sterility in apples.—A cytological study, by the Minnesota station, of pollen development indicated that in the Stayman Winesap variety poor pollen is a result of irregular chromosome distribution at maturation, combined with several types of degeneration in the microspores and pollen grains. The evidence is indicative of a hybrid condition in this variety. Controlled pollination of stigmas of the pistils of two varieties, as well as cytological evidence, showed that pollen tubes pass from one carpel to another. The course of growth of the pollen tube is from the stigma through the conducting tissue of the style to the placenta, where it may fertilize the ovules of the carpel or pass between the edges of the carpel and over the base of the central cavity and enter another carpel through its suture.

Heterozygosis in the Jonathan apple.—The Jonathan apple was found by the Iowa station to be heterozygous to almost every set of factors determining size and form of fruit, flesh texture, flavor, and season. Jonathan apple combined with red varieties gave some solid red seedlings; when combined with yellow and blushed varieties the color tones were diluted to produce striped, mottling, and dull shades. Attempts to introduce the vigor and health factors by crossing Jonathan with other varieties resulted in seedlings showing a heterozygous condition for this factor with promise of some excellent strains.

Size and yield inheritance in beans.—Studies by the Maine station showed that differences in size and total yield of beans are to some extent at least dependent on genetic factors linked with factors for simple qualitative differences and are therefore inherited in the usual Mendelian manner. Yield was associated with single color and pattern differences. Factors for yield were found to be unequally influenced by environmental conditions.

Linkage relations of yellow pigment in maize.—The discovery of two genes responsible for the formation of pigments in maize, both recessive and strictly following Mendelian inheritance, was reported by the Iowa station Linkage tests showed that both genes are borne on the same chromosome Interactions of the genes with the albino genes indicate a fundamental, physiological (or chemical) difference in the yellow pigments of maize, so that one yellow pigment is considered to be independent of the green components of chlorophyll in development and the other not.

Transmission of chemical characters in corn.—Chemical properties such as carbohydrate content were found by the Iowa station to follow a definite system of hereditary transmission. It was shown to be possible to cross sweet corn with field corn to increase the yield without reducing the sugar content of the sweet corn.

Linkage groups in barley.—Of the 7 expected linkage groups of the 14 somatic chromosomes of barley, 4 have been established by the Minnesota station. Resistance to *Helminthosporium sativum* was shown to be due to definite genetic factors, in case of the Svanhals type there being probably at least three factors, one linked with the factor for 2-rowed, one with the factor for rough awns, and one with the factor white glumes. "The factor for early heading was found to be linked with the factor

for 6-rowed. The linkage intensity was very low, the crossover value being 42 per cent. The linkage of the factor for susceptibility to Helminthosporium with the factor for earliness is much more intense than that with the factor for 6-rowed, else earliness in itself predisposes the plant to attack by the pathogene." According to the same station Hordeum species generally fall into three groups in regard to chromosome numbers, the first having 7 pairs and including all of the cultivated species, the second having 14, and the third 21.

Linkage in wheat.—A count of 60 F_2 plants of a cross of Khapli-Mindum × Marquis, by the Minnesota station, showed plants with 14 bivalents and 21 bivalents and univalents to be most frequent. Webster, which is resistant to stem rust, showed 42 somatic chromosomes. Color of grain in Marquis wheat appeared to be the result of two duplicate genes, and grain color in Kanred and Minturki was apparently due to a third independently inherited factor.

Chlorophyll deficiencies in cotton.— Two heritable deficiencies in green coloring matter in cotton seedling, namely, yellow seed leaves instead of the usual green and lack of green color in certain portions of the seed leaves, are reported by the Texas station. The presence of two recessive genetic factors Y_2 and y_1 is shown to be necessary for the expression of this character. One, two, and possibly three different genetic factors, that is, 3:1, 9:7, and 27:37 ratios, were found present in different and in the same families. Also there is a slight possibility that two of these factors are linked.

Chromosomes in potatoes.—The Maine station found 24 haploid chromosomes in commercial varieties of potatoes. Some of the varieties showed lagging chromosomes at the time of the reduction divisions, indicating hybrid origin. In other commercial strains the chromosomes were orderly in their behavior. The chromosome number in wild species varied from 12 to 36, being in all cases multiples of 12.

Sex in spinach.—Sex expression in spinach appears, from studies made by the California station, to be not affected by physiologic factors. Time of planting, light intensity, plant food supply, and spacing of the plants apparently do not alter the sex ratio. That sex is controlled by genetic factors is indicated by the fact that monoecious plants of varying degrees of "maleness" or "femaleness" occur, and these produce in their progeny many monoecious plants with the same degree of sex expression as the parent plant. See p. 31.

Inheritance and evolution in the grouse locust.—A fifth contribution was made by the Kansas station to studies begun in 1906 of inheritance and evolution in Orthoptera, using the grouse locust as material for the study, because of their many strikingly contrasting characters and the ease and rapidity with which genetic studies can be made with them.

Sex control in animals.—Sex control by centrifugal separation of male-producing and female-producing spermatozoa seems possible, according to results of experiments with rabbits and swine reported by the Wisconsin station, for species in which the difference in the sizes of the X-chromosome and the Y-chromosome is a considerable percentage of the total amount of chromatin in the spermatozoa. Whether such a method can be made practicable even for the most favorable species depends upon the possibility of making the technique simple and dependable.

Inheritance of body weight in fowls.—In experiments with Cornish-Hamburg crosses, the Rhode Island station found that both the first and second generation offspring from the cross developed at the same rate as the Cornish breed and attained the same weight at 10 months. Later, however, the Cornish fowls increased in weight slightly faster than the crossbreds. The crosses in both the first and second generations were not more variable than the parents.

Sexual maturity and egg production.—The Missouri station reports investigations which showed that quick-maturing pullets are superior egg producers and make the best winter egg records. There was a slight but perceptible negative correlation between rate of sexual maturity and spring egg production, less variability in spring production than in winter or summer production, and a slight negative correlation between rate of sexual maturity and summer egg production. Little, if any, correlation occurred between rate of sexual maturity and rate of laying as measured by the best month's production or best two months' production.

Inheritance of fecundity in hens.—Results of investigations at the New Jersey stations showed the existence of a winter cycle of egg production for Leghorns similar to that reported by the Maine and Massachusetts stations for Barred Plymouth Rocks and Rhode Island Reds. The investigations indicated the absence of linkage in the inheritance of fecundity.

FIELD CROPS

Of the approximately 5,500 projects reported as active at the experiment stations, over 1,800 dealt with field crops, covering various phases of the improvement, culture, and handling of the principal crops.

Time to cut alfalfa.—The Minnesota station found that alfalfa cut in the hard bud stage four times during the season was not seriously injured. Although earlier cutting than the tenth bloom is not advised as a general practice, if the first crop makes so rank a growth that lodging is apt to result it may be cut before tenth bloom, in order to secure a better quality of hay with no injury to the stand; and later cuttings can be made at tenth bloom.

Improved varieties of barley.—A pure-line selection made by the Minnesota station from an importation which was received under the name of "Switzerland" has, for several years, often yielded 50 to 100 per cent more than any other barley tested. This has been named "Peatland" and is to be increased for distribution. Colsess, a new 6-rowed, hulled, hooded barley produced by the Colorado station as a result of a cross between Coast, a bearded sort, and Success, a beardless or hooded sort, has shown in tests at the station several advantages over other Colorado barley, namely, in yield under irrigation, stiffness of straw, earliness, loss due to shattering, and adaptation to mountain agriculture.

Mat bean as a green manure crop.—The mat bean (*Phaseolus aconitifolius*) was found by the California station to be well suited to use as a leguminous green manure and cover crop for vineyards and orchards, to protect the soil from the hot sun, to prevent the burning out of organic matter, and to leave the irrigation furrows visible and accessible. It is also a drought-tolerant plant which provides pasture and improves the soil and can be rotated with grain.

Corn selection.—The Illinois station found that after 28 years of selection the protein content of corn was raised from 10.92 to 16.6 per cent in the high strain and lowered to 8.38 per cent in the low strain, and the oil content was increased from 4.7 to 9.86 per cent and lowered to 1.51 per cent. Selection increased the height of ear from 49.6 to 92.9 inches and lowered it to 11.7 inches. The yield of a strain was increased 5.6 bushels per acre in 3 years by mass selection, which proved just as effective as continuous ear-row selection.

Time to cut corn.—The Ohio station found that corn cut in the dough stage yielded 42 bushels per acre, when the kernels were fairly hard and ready for the silo 68 bushels per acre, and when mature 78 bushels per acre. The station therefore concludes that feeding immature corn to hogs is a wasteful practice.

Water requirements of corn.—In potometer experiments at the Missouri station with corn grown on fertile soil with varying amounts of moisture during different periods of growth, it was found that the moisture supply during the second period or from the time the plants set their ninth leaves until about tasseling time had by far the greatest effect upon the total dry weight of the plants. Plants stunted by minimum moisture (13 per cent of the soil capacity) during the first period were able to recover and produce good plants, if conditions were favorable during the last two periods, but the time of maturing was somewhat prolonged. Minimum moisture during the third period gave a greater weight of root growth than optimum moisture (28 per cent). In all periods minimum moisture gave a greater root growth in proportion to tops than did optimum, even though the actual weight was less during early growth. Optimum moisture during the third period gave considerably greater production of grain than did the low soil moisture content. The quantity of water transpired per unit of dry matter produced varied greatly in different years with variation in the weather conditions. Variation in transpiration with different treatments was not great, but was slightly less with low soil moisture. In practically all cases the plants contained a higher percentage of nitrogen and mineral elements where the moisture content of the soil was low. The Nebraska station found inbred strains to be less efficient in their water economy than hybrids.

Irrigation of corn.—The maximum yield of corn was obtained by the Utah station with 20 inches of irrigation water. Manure somewhat lessened the loss due to either insufficient or excessive irrigation, and optimum irrigation was found to be especially needed when manure was insufficient. The nitrogen content of corn grown on a highly calcareous soil was decreased by irrigation and increased by manuring. The mineral constituents of the grain were increased by both irrigation and manuring.

Drought-resistant corn.—Drought resistance in corn was found by the Porto Rico station to be correlated with thickness and intensity of color of the leaves, and use is being made of this fact in selecting drought-resistant seed corn.

Foreign v. domestic clover seed.—Germination tests by the Delaware station of red clover seed from nine domestic and foreign sources showed no appreciable difference, but the stand was better with domestic seed. Clover from foreign seed was more susceptible to anthracnose and winterkilling, while American clover was more susceptible to powdery mildew. Medium red clover from seed obtained from Italy, France, Chile, England, and Wales was completely killed, in tests at the Minnesota station, during the winter of 1924–25. Stands from seed from Germany, Austria Hungary, and adjoining countries came, through in fair condition, and plantings from northern-grown American seed were not injured.

Lint and seed characters of cotton.—In a statistical study of 16 varieties of cotton, the Texas station found in all varieties positive correlations between yield of lint and seed, yield of lint and number of 5-lock bolls, yield of seed and number of 5-lock bolls, yield of lint and number of 4-lock bolls, and yield of seed and number of 4-lock bolls. No consistent relation was shown between yield of lint and percentage of lint, yield of lint and length of lint, yield of seed and percentage of lint, yield of seed and length of lint, percentage of lint with length of lint, nor with the percentage or length of lint with either 5-lock or 4-lock bolls.

Delinting cotton seed.—The sulphuric acid treatment for delinting cotton seed was found by the Arizona station to be very effective. The station has devised a machine which applies the method quickly and thoroughly and makes the use of sulphuric acid safe for the operator. The treatment results in surface sterilization of the seed, hastening of germination, increased percentage of germination, greater ease in handling the seed in planting, and a healthier and more uniform stand. Cooperative treatment in a central community plant is recommended. The North Carolina station found that delinting with either sulphuric acid or machinery hastened germination. The acid treatment also reduced disease in the seedlings.

Spacing cotton.—Spacing tests by the South Carolina station showed that closely spaced cotton not only produced larger yields but a much earlier crop and resulted in a change of practice to a marked degree. Cotton spaced 24 inches apart in the drill yielded 1,035 pounds of seed cotton, while 9-inch spacing yielded 1,336 pounds.

Improved flax culture.—The production of flax in the United States declined to a marked extent during the period from 1909 to 1921, but has greatly increased in recent years, according to the South Dakota station. The development and use of disease-resistant varieties have aided in overcoming one of the greatest handicaps to successful flax growing. Careful selection of soil, seasonal seeding, and use of the proper amount of seed are other important considerations. Seeding flax and wheat together was found by the station to have some possible advantages under certain conditions, but the station does not undertake to recommend this as a universal practice. The Minnesota station found that a combination of wheat 45 pounds and flax 42 pounds gave the highest gross returns per acre, $35.22. Flax sown at the rate of 42 pounds per acre alone gave a gross return of $32.79.

Wilt and rust resistant flax.—The Minnesota station found that wilt-resistant varieties do not lose their resistance by being grown on clean soil. Several Argentine fiber strains immune to rust were crossed with seed types, and the F_1 of all crosses have so far been immune, indicating that resistance is dominant. Segregation occurs in the F_2 plants, the majority being immune. There appears to be no correlation between wilt resistance and rust resistance.

Improved varieties of oats.—Improved varieties of oats developed and distributed by the Iowa station, including Iowa 103, Iowa 105, Iowar, and Iogren, it is claimed, are "returning to the State annually more than the total annual appropriation made by the State for the support of the Iowa State College and experiment station combined; more than 15 times the amount appropriated by the State to all of the work of the agricultural experiment station; more than 200 times the funds expended on all the crop improvement work." A survey made in 1924 indicated that 46 per cent of the total oat acreage in Iowa was planted to the 4 pedigreed varieties named. Iowa 103, first distributed in 1913, giving an average increase in yield of 3.73 bushels, was grown on 23 per cent of the oat land; the Iowar, distributed in 1919, giving an increased yield of 5.93 bushels, was grown on 15 per cent of the land. The total increase in production resulting from the growing of these varieties in 1924 is estimated to have been 11,000,000 bushels.

Natural crossing of oats.—The Minnesota station found that the extent of nat-

ural crossing in oats varied with the variety but was not greatly modified by seasonal conditions. The largest percentage of offtypes obtainable was 1.4 per cent in the case of Kanota. Every variety showed some natural crossing. Natural crosses occur somewhat less frequently in oats than in wheat.

Variants of the Burt oat.—The commercial Burt oat, according to the Kansas station and the United States Department of Agriculture, is composed of a large number of distinct strains, many of which are heterozygous. The variety is considered to belong to *Avena byzantina.* Field crosses are apparently frequent. It was found that this oat varies "in many observable plant characters, such as habit of growth of the young plant, leaf color and leaf width, time of heading and ripening, and others. Several distinct variants have been observed, among them one showing a chlorotic condition of the leaves, one having multiflorous spikelets, one with loose paleas, and the false wild forms."

Smut resistance in oats.—The glumes of oats were found by the Kansas station to be a great natural protection to the seed of varieties susceptible to smut, such as Aurora, Richland, Burt, and Kansas 6004. Resistant varieties such as Burt, Kansas 6090, and Kanota are inherently resistant; that is, their resistance is not due to such a large extent to the natural protection afforded by the glumes. Smutted Aurora seed, the glumes of which were not removed, gave 15.1 per cent of smutted heads, while seed from which the glumes were removed gave 56.7 per cent. Resistant Kanota seed, with the glumes not removed, gave 2.7 per cent of smutted heads and 4.5 per cent when the glumes were removed.

Pastures.—Permanent improved bluegrass pastures are, according to the Pennsylvania station, worthy of a more prominent place in economic farm management in regions suited to this grass and should largely eliminate the necessity of growing expensive leguminous soiling crops as supplementary dairy feed. The maximum growth of bluegrass was obtained, in the experiments reported, on soils treated with limestone and a complete fertilizer. Over three times as much crude digestible protein was produced with complete fertilizer on pasture as was produced on the same acreage in a grain rotation.

Burning over of upland pastures during the dry season was found by the Guam station to kill the valuable grasses and allow worthless weeds to take their place. Similar results are reported by the Kansas station. In experiments by the Connecticut Storrs station, lime alone produced no increase the first year, whereas acid phosphate increased the yield of pastures, as measured in pounds of beef maintained or gained, by 45 per cent.

For pastures on hilly land, orchard grass, tall meadow oat grass, red fescue, and sweet vernal were found by the Maryland station to be a very satisfactory mixture, with white clover and lespedeza added for the slopes and mountain valleys. Kentucky bluegrass and orchard grass proved best for pastures. For hay, the tests showed that a combination of alsike clover, alfalfa, and timothy was more profitable for yield and quality than clover and timothy alone.

Seed peas.—The production of seed peas is one of the most important seed-producing enterprises in the United States. The raising of seed peas has been one of the notable agricultural developments in the Northwest. The Montana station, among others in that region, has given much attention to the subject and has recently published detailed instructions for the culture of peas for this purpose, based upon extensive observations and experiments.

Field tests with potatoes.—The technique of field experimentation and the reliability of field experiments are receiving increasing attention. In a study of the experimental error in field tests with potatoes, the West Virginia station found the results to substantiate the conclusions drawn from similar work with other crops; that is, that there is a limit in plat size and number of replications beyond which no practical reduction in experimental error occurs, and that reliable results under West Virginia conditions with potatoes planted 10 to 12 inches in the row and the rows spaced 3.5 feet apart may be expected from the use of a 40-foot single-row plat replicated four times.

Alaska seedling potatoes.—Seedling varieties of potatoes showing marked improvement over standard sorts have been originated by the Alaska stations. The selected seedlings mature early, yield well, and produce large, smooth-skinned tubers of good shape and cooking quality.

Size of seed piece of potatoes.—In experiments at the Montana station, size of tubers varied inversely with the size of the seed piece, small seed pieces resulting in a higher percentage of large tubers, whereas large seed pieces gave

an increase of average-sized tubers. Under irrigation 3-ounce seed pieces gave best results, whereas under dry-land conditions 2-ounce pieces were best.

Storage temperature for potatoes.—From a study of respiration in potatoes, the Maryland station concludes that 40° F. is apparently the best storage temperature. Respiration in potatoes removed from storage at 40° to market temperatures was abnormally high but not half as high as in potatoes removed from storage at 36°. The station concludes that temperatures above 40° can hardly be considered practicable for late storage because the tubers will not be kept sufficiently dormant at this temperature.

Uses and value of the soy bean.—After 15 years' investigation and observation, the Iowa station concludes that the soy bean has more uses in Iowa than any other legume and is well adapted to the climate and soils of the State. It grows well on distinctly acid soils and is a safe and dependable crop. Of 157 varieties tested, Manchu is especially recommended for seed production and Peking for hay and silage. Twice as much seed per acre as is ordinarily recommended has consistently given the most profitable yields of seed and hay. Two bushels of seed per acre of the most commonly grown varieties is recommended when the crop is drilled. Soy beans may be grown alone or in combination with corn. They may be fed advantageously to dairy and beef cattle, sheep, hogs, and chickens to replace, at least partly, such feeds as oil meal and tankage. The soy-bean plant appears to have approximately the same feeding value as alfalfa and may be used in the form of hay, pasture, silage, or soilage, while the seed furnish an excellent protein concentrate.

Yield of soy beans.—Soy beans yielded more than four times as much seed and more than twice as much hay as cowpeas, when grown in rows 42 inches apart, in experiments at the Missouri station. When sown with an 8-inch grain drill, the yield of soy-bean hay was again more than double the yield of cowpea hay, and the yield of seed was 32.2 bushels per acre, whereas the cowpeas yielded less than 3 bushels.

Soy beans and corn.—A combination of soy beans and corn produced an average increase of approximately 1 ton of green forage and 500 pounds of dry matter per acre over corn alone, in experiments at the Connecticut Storrs station. The mixture harvested averaged 1.82 per cent protein and contained 670 pounds per acre, whereas the corn silage averaged 1.54 per cent protein and contained 550 pounds per acre. The experiments indicated that approximately $10 per acre will be added to the value of the silage by planting soy beans with corn.

Improvement of soy beans by selection.—The North Carolina station found that selecting soy beans for high yield is more important than selecting for high oil. High oil and low protein content are usually associated and vice versa.

Soy bean inoculation.—The soy bean radicicola organism, according to the New Jersey stations, does not tend to become adapted to specific host varieties of soy beans. The differences in nodulation found in several varieties of soy beans appeared to be due to some physiological difference in the varieties, possibly in ability to conduct carbohydrates to the roots or proteins away from them. In a study of the effect of bacterial numbers on the nodulation of Virginia soy beans the New Jersey stations found that "when the number of nodular organisms is limited there is a distinct relation between the number of organisms present and the number of nodules formed. There is a rather definite minimum number of nodular organisms required to produce maximum infection. After a certain degree of infection is reached the host is immune to additional infection."

No legume had been found by the Illinois station which consistently cross inoculates with the soy bean. Under laboratory conditions some strains of cowpea bacteria apparently had the power to cause infection on the soy-bean plant. A large number of previously unclassified legumes were found to belong to the cowpea group. Certain varieties of soy beans were apparently less susceptible to bacterial nodule infection than others. The total weight of nodules on a plant is thought to be a better index of its nitrogen-fixing ability than the number of nodules present. The strain of bacteria was also found to be an important factor. Inoculation and liming materially increased the yield of soy beans on acid soils which were not in a high state of fertility. A combination of the two gave a more satisfactory return than either alone. The protein content of the soy bean was greatly increased by inoculation.

Imported sugar beet seed.—Michigan-grown sugar beet seed from unselected commercially grown foreign seed gave beets of comparatively high tonnage, low sugar content, and low purity, in experiments reported by the Michigan station. Beets grown from many of the foreign seeds differed materially in their

producing power. Since the Michigan beet sugar industry is largely dependent upon foreign grown seed, the importance of developing strains which will give not only high tonnage but high sugar content and purity as well is evident.

Mosaic-resistant sugar cane.—Progress in developing an improved mosaic-resistant strain of Japanese sugar cane and encouraging the growing of such cane is reported by the Porto Rico station. Soaking seed cane for three or four days in limewater was found to destroy stalk borers and stimulate germination and early growth.

Paper mulch for sugar cane.—Paper mulch increased the tonnage of plant cane at the Virgin Islands station but not enough to pay for the paper.

Sunflowers with corn for silage.—A mixture in the proportion of 1 bushel of sunflower seed to 8 of corn gave an average yield of 19.5 tons per acre, in experiments at the New Hampshire station. The sunflowers increased the tonnage materially but increased the cost of harvesting, the heavy heads breaking the stalks and increasing the cost of loading and putting them through the cutter. There was no disadvantage in feeding the mixed silage from the standpoint of milk production, and the cows ate it as readily as they did corn silage.

Cover crops and rotations for tobacco.—The Maryland station found that the frequent and persistent use of soil-improving crops such as vetch, cowpeas, and crimson clover, either with continuous culture of tobacco or in short rotations, did not give as uniformly good yields and quality of tobacco as does the old system of resting the plant for a period of years after one or more crops of tobacco.

Timothy as a cover crop proved harmful to tobacco in experiments at the Massachusetts station, probably partly due to an increase of brown root rot under the crop.

Chemical constituents of different grades of tobacco.—In a study of the relation of certain constituents of tobacco to grade, the Kentucky station found that the best tobacco of any grade usually contained a larger percentage of nicotine than the common. The nitrogen and nitrate were more variable but in the majority of cases were higher in the good tobacco than in the common. In the Burley grades the fillers usually contained the largest percentages of nitrogen and nicotine and the smokers the smallest. In dark tobacco the leaf usually contained the largest percentage of nitrogen, nicotine, and nitrate, and the trash the smallest. There was considerable variation in the ash constituents of different grades, but apparently the good grades contained most potash.

High-protein wheat.—A study by the North Dakota station of the protein content of hard red spring wheats over a period of 15 years showed that climatic conditions are an important factor in determining the protein content of the crop. Low temperature during the growing season produced low-protein wheat, whereas high average temperatures during June and July produced high protein. Rainfall variation was not as important as temperature, but wheat in seasons of very low rainfall was high in protein. Soil fertility and preceding crops affected the protein content, and by the use of legume crops such as clover, sweet clover, and alfalfa, high-protein wheat was produced in seasons when climatic conditions favored the production of low-protein wheat. The relative protein content of different varieties showed variations in different sections of the State, evidently due to the reaction of the variety to climatic conditions.

Hard grain strains of wheat have been isolated by the Arizona station from a soft strain of Early Baart. These strains grown for four years under irrigation were fully as hard as the grains originally selected. Flour of these hard strains was about 6 per cent higher in absorptive power and about 2 per cent higher in gluten content than that of the soft parent. Apparently the quality of the gluten was not materially improved, because the loaf volume was not increased, although the bread yield was increased as a result of the greater absorption.

In a study of correlation between the capacity of wheat to increase its protein content under fertilization with nitrate of soda and of the two heritable properties of ratio of grain to total weight and capacity to ripen after treatment, the California station found evidence of such correlation in a considerable number of varieties. The protein content was markedly affected by manipulation of the supply of the nitrogen in the growth media, but evidently there were other factors which probably affected the rate of supply of nitrogen to the plants.

Length of head and yield of wheat.—Selection of long heads of wheat in the field is not a means of increasing the yield of a variety, according to investigations reported by the South Datoka station. Length of culm was corralated with the length of head that it bore, but there was no correlation between length of head and the length of culm produced by these heads in the succeeding gener-

ations. Long heads were as a rule borne on long culms, but seed from long heads did not necessarily give plants with long culms. The highest average yield of Marquis wheat for four years was obtained from strains that came from mother heads of 11.5-centimeter length.

Pollen production by wheat.—Different varieties of wheat vary in the amount of pollen produced, according to studies reported by the North Dakota station. There appeared to be a close relationship between length of anthers and pollen-bearing capacity.

Green manures for wheat in Alaska.—Wheat gave a larger yield following potatoes than after various leguminous green manures, in experiments reported by the Alaska stations. This is attributed to exhaustion by the green manure crops of the soil moisture, which was limited by deficient rainfall.

Effect of irrigation on mineral constituents of wheat.—The iron content of wheat was found by the Utah station to increase with the quantity of irrigation water applied during the growing season. Wheat grown with 35 inches of irrigation water contained 169 times as much iron as did similar wheat grown without irrigation. The chlorine content of wheat was found to vary directly with the amount of water applied during the season. Wheat receiving 35 inches of water contained 27 times as much as that without irrigation. The sulphur content of wheat also increased with quanity of water applied.

Irrigation requirements of crops.—The New Mexico station obtained the best results with alfalfa from about 50 inches of water applied in 5-inch irrigations; with wheat, from about 15 to 20 inches, applied in 4-inch irrigations. With various other crops the duty varied widely with the crop. The irrigation season for alfalfa was about 6.5 months, and for wheat, about 8.5 months, from October 4 to June 15. The irrigation season for the other crops grown was between February 21 and October 25, depending on the crop. The yield of most of the crops included in these investigations seemed to be more closely correlated to the amount of water applied than to the soil type. The yield of alfalfa per acre-inch decreased with amount of water applied. The yield of wheat per acre-inch varied from 27 to 201 pounds.

Weight of seed.—In soil cultures by the New Jersey stations with soy beans, buckwheat, Lima beans, and corn, seeds of high medium weight produced better plants, from the standpoint of several quantitative plant measurements, than did seeds of lighter weight or abnormally heavy seeds, but the superiority of plants grown from heavier seeds over those grown from lighter seeds decreased notably as the plants approached maturity, sometimes disappearing entirely.

Weeds and weed control.—Destruction of weeds is the principal benefit of cultivation of corn on the brown silt loam soils of Illinois, according to the Illinois station, and for this purpose shallow cultivation is preferable to deep. Deep cultivation of corn may result in root injury and decreased yields. Weedy corn probably suffers more from a lack of nutrients than from deficiencies of moisture under the climatic conditions under which these experiments were made. Need of cultivation seems to be no greater in dry than in wet years; it may, in fact, be less.

Weed killing, according to the Missouri station, should be the chief purpose of cultivation of corn. There is no need for deep cultivation with its consequent root pruning, nor for any extra late cultivation of corn. The mere scraping of the surface sufficiently to kill the weeds resulted in yields equal to those obtained by deeper stirring of the soil. In ordinary seasons three cultivations to a depth of 2 to 3 inches with care to kill the weeds gave the largest net return from the corn crop with the least expenditure of labor. This appears to be in general accordance with results reported by other stations.

Certain rotations, according to the South Dakota station, permit the growth of some species of weeds while inhibiting others. General directions for keeping land free from weeds will, as a rule, not suffice and different kinds of weeds must be dealt with individually. Continuous small grain on land gives rise to increasing admixtures of wild oats, which can be practically eliminated by cutting the small grain before the wild oats develop seed. An ordinary rotation of corn, oats, and sweet clover was found to be ineffective in holding perennial peppergrass in check and may even aid in the dissemination of quack grass and the small flowered morning glory.

HORTICULTURE

Irregular bearing of the apple.—The bearing habit of apples may vary within the variety, but is in the main a variety characteristic, according to the Ohio station. The varieties tested by the station are roughly classified as follows:

(1) Annual bearers, or those varieties which have a tendency to produce

a crop each year, including Baltimore, Ben Davis, Bonum, Gano, Grimes Golden, Nottingham, Rome Beauty, San Jacinto, and Stayman Winesap. (2) Biennial bearers, or those which produce a crop one year and little or no fruit the following year, as, for example, Red Astrachan, Baldwin, Fall Jennetting, Jefferis, Loy, Oldenberg, Oliver, Wealthy, Yellow Transparent, Arkansas, Family, Summer King, Liveland, and Hubbardston. (3) Alternate bearers, or those which produce a heavy crop one year followed by a light or scattering crop the next year. In this group are Winter Banana, Boiken, Charlamoff, Early Harvest, Fallawater, Mann, Mother, Northern Spy, Rambo, Red Canada, Rhode Island Greening, Stark, White Pippin, Jonathan, King David, and McIntosh. (4) Irregular bearers, or those which may produce two or three successive crops followed by several seasons in which little or no fruit is produced. These varieties generally do not have a high average yield. The following might be placed in this group: Babbitt, Golden Russet, Greenville, Peck Pleasant, Yellow Bellflower, Blenheim, Fameuse, Red June, Yellow Newtown, and Tompkins King.

In a study of annual and biennial bearing in York Imperial apples the Missouri station found that in the off year spur growth was short, the set was poor, and the percentage of blossom buds formed was high and independent of spur growth. In the on year spur growth was longer, a large crop set, and few blossom buds formed. "There was no correlation between the growth of the individual spur in successive years. In annual York Imperial, nonbearing spurs were longer than on alternating trees; about one-third of them formed blossom buds and the percentage of set was very high. There was a correlation coefficient of +0.45 between the growth of individual spurs in successive years. It is concluded that the biennial trees were deficient in carbohydrate the on year and in nitrogen the off year and that these deficiencies acted as limiting factors on spur performance, causing the tree to act as a unit. In annual trees these limiting factors had been removed by nitrate of soda applied the middle of September for four consecutive years, and spur performance was individual. It is suggested that supplementing spring applications of nitrogen the off year by fall applications may be helpful in establishing and maintaining annual bearing."

Fruit bud formation in apples.—In experiments at the New Hampshire station fruit buds were formed most abundantly when the supplies of carbohydrate, water, and nitrogen were approximately balanced. When the accumulation of carbohydrates was excessive and the supplies of water and nitrogen were low, flower formation was reduced. No fruit buds were formed by bearing spurs, although they were of almost exactly the same composition as the nonbearing spurs which formed fruit buds abundantly. This was apparently due to the inhibiting effect of the rapidly growing apples on these spurs, as was the case with rapidly growing terminal buds on any shoot which inhibited the growth of lateral buds on the shaft. It was found also that developing fruit upon the spur had a tendency to restrict fruit bud formation upon an adjacent spur. This is in accordance with the long observed fact that spurs upon a tree carrying a large load of developing fruit would be much less likely to form fruit buds than those on a tree not carrying a heavy crop. Studies by the California station showed that the various deciduous fruits differentiated their fruit buds from the middle of June until the first of September under California conditions. Apparently differences in cultural treatment and environment had little or no effect on the time of fruit bud differentiation.

Bud selection in apples.—Buds selected from large productive trees as compared with buds from small unproductive apple trees made little difference in size of nursery stock, in experiments at the Maine station. There was some increase in size of the 1-year whip due to the rate of growth of the grafted bud in the spring, but little effect was observed in the case of the 2-year-old tree. The size of the seedling rootstocks had more influence on the size of the 2-year whips than on the size of 1-year-old trees. The correlation between seedling size and size of a 2-year-old nursery tree was found to be about 0.4 in four varieties.

Winter injury in apples.—Studies at the Minnesota station indicated that apple trees increase in hardiness until January, at which time maximum hardiness for the variety is reached. It remains relatively constant during the remainder of the winter. Dormancy is not a significant factor in winter injury in Minnesota, although the time of breaking dormancy is variable from season to season. The factors of greatest importance seem to be the maturity of the tree in the fall, the time at which severe temperatures occur in early winter, and the minium temperature reached. It was found that twigs of the hardy

Duchess variety respired more carbon dioxide than did the tender Delicious variety, but responded more slowly to changes of temperature. Microscopical examination of tissue which had suffered winter injury showed that browning was localized in individual cells and that the depth of browning was a function of the number of cells killed. By evaluating this in the different parts, a numerical expression of injury was developed. Desiccation during the winter did not account for the differences in winter injury. Considerable quantities of sap were centrifuged from apple trees during the winter months, showing that free water was present in the trachea. The Montana station observed that clean cultivated orchards suffered most from winter injury, whereas those with some form of cover crop, as alfalfa, came through in good shape and made better growth accompanied by a more regular setting of fruit spurs and fruit buds.

Cover crops for apple orchards.—Measurements and records by the Washington station of tree growth in orchards that have been in cover crops for seven years or more indicate that maximum growth and vigor consistent with high yields of fruit of satisfactory quality have been attained. The growth of tree and fruit, however, continues until late in the season, so that high color and satisfactory quality are not attained until the fruit is beginning to ripen on the tree. The Montana station points out that unless the soil is exceptionally good the use of alfalfa as a permanent cover crop in orchards must be accompanied by the use of commercial fertilizers.

Orchard management.—The Iowa station has had particularly good results with apple trees grown continuously in clover sod. Trees grown on clean cultivated and cover crop soil were severely winter injured. Trees on blue grass sod for 15 years were healthy at the end of the experiment but lacked general vigor and produced low yields, on the average about 3 bushels per tree less than on clover sod. Trees with good exposure to sunlight produced 100 per cent more fruit than those under shaded conditions. There was found to be a correlation between circumference, terminal fruit buds, leaf growth, and production. Trees producing a low yield as a result of growth in blue grass sod for 10 years were completely rejuvenated by the application of 15 pounds of nitrate of soda per tree two weeks before blooming. High production was found to be generally associated with a low ratio of nitrogen to carbohydrates, and vice versa.

Nutrition of apple trees.—Seedling apple trees grew equally well in sand cultures with a considerable range of nutrient combinations, in experiments at the New York State station. Vigorous vegetative growth was secured with the nutrients in widely different proportions, provided the total concentration of nutrient ions was low. Low concentrations maintained at a constant level were conducive to best top and root development, although in some cases a concentration four times as great produced remarkably good development, provided a proper balance of ions was maintained.

Physiological changes in apple trees due to pruning.—Nitrogen was found by the Missouri station to be translocated in the spring from the older wood to the tips of the shoots. A spring application of sodium nitrate increased the nitrogen content of the tips and decreased it in the middle of 1-year-old wood. Heading increased carbohydrate consumption and thinning conserved the nitrogen and carbohydrate supplies of the tree. Heading back the leader diverted the nitrogen to unpruned laterals.

Fertilizing apple orchards.—Results of fertilizer experiments on apple orchards at the Maine station are in accord with those of similar experiments elsewhere in showing little effect from fertilization in cultivated orchards. However, two annual applications of nitrate of soda to mature Ben Davis apple trees in sod at the rate of 6 and 12 pounds per tree more than doubled the yield of fruit. Applications of phosphorus and potash seldom if ever increased yields. The greatest need for nitrogen in orchards, according to the Illinois station, appears to be in the spring, when growth begins and when the trees flower, the nitrates in the soil being especially low at this time. However, since the apple is a perennial, nitrogen applied in the summer may result in the storage of nitrogenous materials in the tree which would later be usable when needed.

Comparison by the New Hampshire station of a fertilized with an unfertilized orchard during 17 years showed that during the first 10 years the difference in yield was not significant, but after that period there was an increased yield of the fertilized trees due, evidently, to a considerable extent to the larger size of the trees produced by the fertilizer applied during the first 10 years. The total increase in production for the 17 years was not sufficient to pay the total fertilizer bill plus the compound interest for the years in which no return was received; however, the

inventory value of the trees based on their present apparent ability to remain permanent fruit producers is much greater than the present appraisal of the trees on the unfertilized plat. From this viewpoint the fertilizer has been used at a profit.

Cold storage of apples..—In the cold storage of apples it is particularly important to know the initial freezing point and the aftereffects of the freezing. The New York Cornell station found the freezing point of the fruit of 10 varieties of apples to vary from −2.85° C. (26.87° F.) to −1.02° C. (30.16° F.). The freezing point and the lethal point in apple tissue were not identical; the latter may be less than 1° C. (1.8° F.) lower than the freezing point, but in some cases there is a difference of nearly 3° C. (5.4° F.). Rapidly frozen apples showed a larger amount of discoloration than those frozen more slowly. Slightly frozen apples were usually more susceptible to *Penicillium expansum* and other fungus organisms and did not keep so well in storage as did normal fruit. The experiments indicated that −1° C. (30.2° F.) or somewhat below this point is the optimum cold-storage temperature for the apple.

Wealthy apples properly ripened and carefully handled were successfully kept in cold storage at the Iowa station until late February. The best results were obtained with fruit stored immediately after picking. Apple scald was a factor of importance only in the case of immature fruit. Soft scald was abundant in case of delayed storage of immature fruit. Highly colored apples have longer storage life, according to the Washington station, and are less subject to wilting in common storage than poorly colored fruit of the same size and date of harvest. Large sized fruits were softer and became mellow earlier in storage than small or medium sized. The station has devised a simple apparatus for testing the degree of ripeness and the condition of apples in storage.

Self-sterility of sweet cherries.—Sweet cherries are generally, if not invariably, self-sterile, a fact which accounts for failures in many orchards. The California station finds that "probably the safest way to obtain a high producing sweet cherry orchard at the present time is to plant a seedling orchard (Mazzard or Mahaleb), and later topwork the branches with scions taken from desirable strains."

Early picking of cherries.—The Oregon station found that cherries picked prematurely were undersized, low in sugar, and high in acidity, and lost weight readily after harvest. Early-picked cherries, when canned, were small in size, dead in color, soft in texture, and flat in taste. Mature cherries showed a gain in sugar content of 10 or 11 per cent. There was no indication that cherries improved in quality after picking. Early-picked fruit tended to become more acid and bitter in storage.

Fertilizers for citrus fruits.—Expenditure for fertilizers is one of the largest items of expense in citrus culture in California, amounting to about $60 per acre per year. The California station found that the use of fertilizers is necessary if crop production is to be maintained. Nitrogen, however, is the only fertilizing constituent, and organic matter the only other material necessary for this purpose. At least one-half of the nitrogen should be supplied in some bulky organic form, preferably in the fall. The concentrated and more quickly available forms should be applied in the spring. From 2 to 3 pounds of nitrogen per tree per year is ordinarily the most profitable amount to use.

Weekly analysis of grapefruit by the Florida station over a period of six weeks from trees receiving different sources of nitrogen gave no indication that sulphate of ammonia produced a less acid fruit, as is generally claimed by citrus growers.

Pruning grapes.—Pruning experiments at the New Jersey stations indicated that grape canes of medium length are more productive than shorter or longer canes. It was found that canes starting from wood older than 2 years were just as productive as canes starting from younger wood.

Some striking results were obtained, by the California station, by varying the amount of pruning and thinning of Muscat vines. By omitting pruning the crop was increased 279 per cent but with a lowering of quality. By thinning the blossoms of vines not pruned the crop was increased 84 per cent with an increase of 175 per cent in the average weight of the bunch and of 17 per cent in the weight of the berry.

Spray injury to peaches.—The New Jersey stations found that spray injuries appeared mainly as the leaf burning which may result in premature defoliation, as necrotic areas at the older nodes of the new growth, or as cankers on the 1-year-old wood which cause a splitting of the bark and gummosis. Atomic sulphur, flowers of sulphur, and lime, alone, caused no injury. Powdered arsenate of lead, 1.5 pounds to 50 gallons of water, alone or in combination with sulphur or lime, caused se-

vere injury. Sprays applied early in the season caused more injury than those applied later.

Core breakdown of pears.—The Oregon station found that core breakdown of pears could be controlled by picking at the proper time, without sacrifice of either yield or quality, A pressure tester devised by the station has proved to be a reliable indicator of maturity and an effective aid in controlling the trouble. The disease did not seem to be affected by the kind or length of storage.

Fertilizers for strawberries.—Nitrogen alone or in combination with phosphoric acid and potash in every instance increased the yield of strawberries, in experiments at the Michigan station. Summer application of fertilizers gave better results than spring application. The largest yields were obtained by fertilizing during both the spring and summer periods and again in the spring of the fruiting year. Nitrogen appeared to be the chief limiting element. Variations in the nitrogen content of the plant at the time of fruit bud differentiation had a greater effect on the yield of fruit than variatians in carbohydrate content. Fruit-bud differentiation did not appear to depend on a particular nitrogen-carbohydrate ratio, although low nitrogen was associated with low yields and high nitrogen with high yields. However, plants with a high content of both nitrogen and carbohydrate were most productive. Purpling of the foliage in the summer or early fall indicated a deficiency of available soil nitrogen. Ammonium sulphate was more effective than sodium nitrate in increasing growth and production.

Germination of asparagus seed.—Asparagus seed under average field conditions germinates slowly. The California station found soaking the seed in water for from three to five hours at a temperature of 25 to 30° C. (77 to 86° F.) to be a practical means of greatly hastening germination.

Sex in asparagus.—In a study of the secondary sex characters in asparagus, the California station noted that in a large population there were approximately equal numbers of staminate and pistillate plants and that during the first and second seasons' growth from transplanting of the crown, staminate plants produced a greater number of stalks on each crown than did pistillate. During the first harvest season the staminate plants outyielded the pistillate throughout the entire cutting period, the difference being greatest during the early part of the season. The average number and weight of spears from a crown were also greater from staminate than from pistillate plants, but the average weight of the individual spears from pistillate plants exceeded that of spears from staminate plants.

Growth of asparagus shoots.—The most mportant external factors affecting the growth of asparagus shoots are, according to the Arizona station, temperature, moisture content of the soil, and salt balance of the soil. Growth at any given temperature may be varied by changing the salt balance. The addition of sodium salts in medium or low concentration improved the salt balance. The height at which the stalk branched was controlled mainly by the temperature.

Blanching celery.—Celery can be effectively blanched by ethylene or acetylene, according to the Minnesota station, in concentrations of 1 part of gas to 1,000 of air, or lower concentrations within 6 days for the self-blanching or within 12 days for the green winter varieties. The use of acetylene for blanching, however, was not so satisfactory. Celery when treated with ethylene did not turn green again in sunlight within the usual time required for sale. In quality, texture, flavor, and color celery blanched with ethylene was equal, if not superior, to that blanched by other methods, and the keeping qualities were not impaired by the treatment. This new method of blanching seems to be of commercial value, since the gas is inexpensive and can be easily applied. The ethylene treatment did not affect either the yellow or red pigments, but acted on the green pigments, speeding up the process of etiolation, which naturally occurs when the plants are in darkness, and improving the flavor of the celery. There appeared to be also a liberation of enzymes which caused production of sugars from the digestion of starch and cell wall materials, thus improving both the flavor and texture. Blanching of some varieties was hastened apparently by infection with mosaic disease. Chlorotic varieties were more easily blanched than dark-leafed plants.

Changes in celery during storage.—Reducing sugars were found, by the New Hampshire station, to be relatively abundant in the inner leaves and petioles of celery after storage. There was an increase in the amount of reducing sugar shortly after the plants were placed in the pit, which then remained practically stationary. On the other hand, the sucrose increased steadily for some time during storage. The celery became increasingly sweeter and more

tender as the storage period advanced, due rather to the gradual increase in sucrose than to the sudden rise of reducing sugars at the outset of storage.

Acid tolerance of lettuce.—Experiments at the Michigan station showed that under some conditions lettuce is an acid-tolerant plant. Ordinary and even unusually high soil acidity per se did not prove to be detrimental to its growth. In fact, it did best in a medium of growth that was distinctly acid in reaction, when the necessary nutrient materials were present in proper quantities and proportions. The experimental evidence "leads to the belief that the very general and more or less promiscuous use of lime on lettuce soils is not only unnecessary but probably harmful."

Sterilizing greenhouse soil.—Sterilization of greenhouse soil by drenching with formaldehyde was found by the Ohio station to be effective against rosette and "drop" diseases of lettuce, but was of little value for control of wilts and nematodes of tomatoes and cucumbers. Steam sterilization either by inverted-pan, hollow-tooth harrow, or buried-tile methods while expensive was generally effective.

Varieties and strains of peas for canning.—Of the more than 500 so-called varieties of peas tested by the New York State station to determine their value for canning, many appeared to be merely "strains." Varieties which showed special promise for canning purposes were Horal, Badger, Lincoln, Richard Seddon, Duke's Delight, Chelsea Gem, Witham Wonder, Mighty Atom, and Little Marvel. It is recommended, however, that before large plantings are decided upon preliminary tests be made of the strains existing in practically all well-known varieties of canning peas.

Inoculation of canning peas.—Inoculation increases both quality and yield of peas for canning, according to experiments made by the Wisconsin station. It increases both the total yield and the percentage of the smaller sizes of peas, produces peas of a better quality and higher protein content, maintains for a longer time the best condition of the peas in the field, and increases succeeding crops grown on the land following the peas.

Alaska canning-pea seed.—Strains of the Alaska pea which ripen in the interior of Alaska in the average season have been developed at the Fairbanks and Matanuska stations. These appear to have possibilities when purified by further selection and roguing as sources of seed for canning peas in the States. Peas grown from the Alaska seed appear to be more vigorous than those from ordinary commercial seed.

Forcing rhubarb.—Temperature proved to be the most important factor affecting color of forced rhubarb, in experiments at the Illinois station, the lower the forcing temperature the darker red the stalks. Higher temperatures, however, produced earlier yields. Watering the roots during forcing increased the yield threefold and did not "wash out" the color of the stalks. In general, older roots produced larger yields, but 1-year-old and 2-year-old roots produced the largest net profits. A rest period, including freezing, appears to be essential to profitable forcing, 6 weeks being better than 1 or 2 weeks. A light freezing (20° F.) was sufficient to break the rest period, while a severe freezing (−10° F.) was injurious and reduced the yield. A brief, thorough freezing seemed as effective as freezing throughout the rest period.

Sex expression in spinach.—Commercial varieties of spinach are frequently mixed, of unsuitable types, or incorrectly named, according to the California station, and this highly heterozygous condition is the cause of much loss to growers and canners. Spinach is shown to be tetramorphic, producing (1) "extreme males," (2) "vegetative males," (3) monoecious plants, and (4) "female" plants. Environmental influences such as varying nutritive conditions, shading, spacing, date of planting, and mutilation appeared to have little or no effect in determining which type would develop. In general the ratio of male and female plants was 1 to 1, although some strains seemed consistently to produce a slight excess of male plants, while others of the same variety produced an excess of females. This fact, if borne out by further tests, may be utilized through plant-breeding methods to the advantage of the seed grower, who would prefer to have an excess of females in the population. Thinning appeared to be the only cultural treatment affecting the sex ratio in spinach that is likely to be of any value for the seed grower. If the seeds are sown thickly and the smaller plants are rogued out early in the season, those remaining may present an excess of females.

Fertilizing spinach.—Experiments by the New Hampshire station showed that spinach needs heavy fertilization, and that commercial fertilizers may be substituted for stable manure to a considerable extent for this purpose. Spinach receiving lime was much better than that on unlimed soil.

Storage of squashes.—Contrary to earlier recommendations, the Vermont station found that squashes kept better in a cool, dry room than in a warm, dry room. A storage temperature of 50° F. or above tends to induce heavy losses in weight, as a result of rapid destruction of carbohydrate food materials. Temperatures of 10 to 20° above freezing retard these changes and maintain the quality and palatability of the squashes through a longer period.

Setting of tomato blossoms.—The Oklahoma station found that tomato plants did not set a high percentage of fruit during the winter months when the humidity was low, and the blossoms that did set showed a high percentage of abnormally elongated styles and a dry and blackened condition of the stigma. The fruit that set very often had no seed, indicating that the failure to set fruit was due to a lack of fertilization.

Acid phosphate for early tomatoes.—The New Hampshire station found that acid phosphate prolonged the early yield of tomatoes. This is ascribed to earlier growth and production of blossom clusters rather than to hastening of the rate of ripening of individual fruits after the blossoms had set.

Hawaii sweet corn hybrid.—A promising hybrid of Henderson sweet corn and Guam corn, having the grain character of the sweet corn and the vigorous growth and leaf hopper resistance of the native sort, has been developed by the Hawaii station.

Seedling sweet potatoes.—Promising seedling varieties of sweet potatoes have been developed by the Virgin Islands station. Of 300 seedlings tested for several years, 7 have uniformly proved superior to the parent plants in every respect, and several others are promising.

Slips v. vine cuttings of sweet potatoes.—In comparative tests at the North Carolina station, larger yields of sweet potatoes were obtained with cuttings than with slips.

Relation of water level to growth of vegetables.—According to the Minnesota station, vegetables apparently differ in their response to depth of water level in the soil. In general root crops require a drier soil, i. e., deeper water level than the leaf crops. A high water level is an effective protection against light frosts, especially in case of potatoes and sweet corn.

Manure substitutes for truck crops.—Substitutes for manure in market gardening have become a necessity. The Rhode Island station, which has given the matter particular attention, reports comparisons of manure alone and of various combinations of manure, green manures, and peat with commercial fertilizers. Replacing one-half of the manure with a complete commercial fertilizer increased the yields of early crops of cabbage, tomatoes, and lettuce over those obtained with manure alone. Peat composted with lime and commercial fertilizer gave 16 per cent larger yields of cabbage than manure alone but lower yields of tomatoes and lettuce. Practically no advantage resulted from adding stable manure to green manure at the rate of 8 tons per acre.

Almond growing.—Almond production has become an industry of considerable importance in the United States. According to recent figures, there are now approximately 100,000 acres of bearing and nonbearing trees, and extensive areas are still being planted. Over 99 per cent of the present American crop is raised in California. The almond tree is in many ways easy to grow, but it has certain special pollination, climatic, and soil requirements. All varieties tested by the California station were self-sterile; some were intersterile. In order to insure cross-pollination it is necessary therefore to interplant varieties which are not only interfertile but blossom at about the same time. A system of interplanting to secure proper pollination, as well as other cultural requirements, has been worked out by the station.

Culture of tung-oil trees.—The Florida station found that the multiple fruiting habit, or bearing more than one fruit on the terminal of an individual twig, can be transmitted by means of buds or grafts. The tendency to make a vertical growth of several feet before lateral branches were formed was corrected by the removal of a narrow strip of bark about an inch in length just above a lateral bud, when a lateral branch soon started.

Fertilizers for coffee.—Coffee responded especially to nitrogen and potash fertilizers, in experiments at the Porto Rico station. Ammonium sulphate gave better results than nitrate of soda. The best results were obtained on those plats receiving nitrogen and potash but not phosphoric acid.

FORESTRY

Cottonwood.—The cottonwood is one of the most rapid wood producers, according to the Iowa station. Plantations 35 years old on overflowed land unsuited for agricultural crops produced in lumber and cordwood an average annual return of $10 per acre

in addition to 6 per cent compound interest on the money invested. Waste land produced in fence posts an annual profit of $5.67 to $7.39 an acre in addition to a like interest on the investment. Cottonwood fence posts for local farm use have been grown profitably on land valued as high as $100 an acre. Cottonwood lumber has proved very serviceable for rough construction work in barns, sheds, and similar purposes, especially in places protected from the weather and from contact with the ground.

Eucalyptus.—The eucalyptus, which is grown more extensively in parts of California than elsewhere in this country, has been shown by the California station to have value for fuel, charcoal, insulator pins, and small turned articles, but not for lumber because of excessive checking and warping of the wood in seasoning. The blue gum makes the most rapid growth of any eucalyptus species thus far planted in California, namely, a mean annual growth of about 3 cords per acre.

DISEASES OF PLANTS

The heavy toll that disease takes of farm crops is reflected in the large number of plant disease projects carried on by the stations. The number of projects on this subject reported as active during the year was 482. Investigations on diseases of cereals and potatoes were especially numerous and active, but the work covered a wide range, as the following examples show.

Disease resistance.—Resistance as a means of controlling disease is receiving particular attention with very promising results. This has been found especially true in case of cereal diseases. The Minnesota station finds that morphology sometimes plays an important part in the resistance of varieties, and that resistance can be altered by changing the morphology of the plants by different systems of fertilization. Certain varieties and species of Berberis were found to be apparently resistant to *Puccinia graminis* on account of their resistance to puncture and consequent inability of the sporidial germ tubes to penetrate.

Take-all disease.—A study, by the New York Cornell station, of take-all disease of cereals and grasses (*Ophiobolus cariceti*) showed that a very large portion of the Gramineae is subject to the disease. Apparently spring planted barley and oats growing under field conditions either escape or are immune to the disease, and spring planted wheat becomes infected only under conditions which are extremely favorable to the organism. Rye is apparently very much more resistant than wheat under greenhouse conditions. Wheat is the most susceptible of the cereals. Barley is more resistant than wheat but less resistant than rye, which is very slightly affected. Oats and rice appear to be immune. Apparently winter wheat is the only cereal likely to be seriously damaged by take-all under New York conditions. No variety of wheat tested was found to be immune to take-all, although there appeared to be marked varietal differences in susceptibility. There was apparently a direct correlation between climatic factors, such as moisture and temperature, and the amount and severity of the disease. There also appeared to be a definite relation between the hydrogen-ion concentration in the soil and the severity of the disease. Least disease was observed in plants growing in media having pH values of from 2.3 to 4.

Wheat rosette.—Wheat rosette, according to the Illinois station, is not the same as take-all due to *O. graminis*. The causative agent was not determined, but the indications were that it is a phase of a mosaic disease. The causative agent was found to be soil-borne and the disease recurred every year when susceptible varieties of winter wheat were sown on infested soil. The disease was not noted in spring wheat. It is stated that since the disease occurs in relatively few varieties it can be successfully controlled by sowing those which are resistant.

Cereal rusts.—The Minnesota station found that the urediniospores of *Puccinia graminis* germinated very quickly, the germination being stimulated somewhat by host tissue. The temperature requirements of leaf rusts seemed to be narrower than those of stem rusts. It was found that the aeciospores may begin to germinate in less than one hour at 10 to 15° C. The addition of wheat leaf tissue stimulated germination. Some spores remained viable for 19 days in a relative humidity of 80 per cent and a temperature of 12° C.

Stem rust of wheat.—The native barberry (*Berberis fendleri*) was shown by the Colorado station to be a host of stem rust. It was found that the emigration of stem rust in the absence of barberry reduced by more than two weeks previous infection dates, which, in normal years, is sufficient to allow wheat to get past the danger stage. The Nebraska station found a direct relation between the viability of the

urediniospores of stem rust and temperature and humidity. Viable spores capable of producing infection were held a year at a temperature of 5° C. and a humidity of 50 per cent.

Black point of wheat.—Seed disinfection with organic mercury compounds was found by the North Dakota station to decrease materially internal infection of wheat with black point caused by *Helminthosporium sativum*, but since the disease may come from other sources than seed, and infections of leaves, heads, and grain may occur independently of seed infection, seed treatment must be supplemented by other control measures such as seed selection, crop rotation, and resistant varieties. The life of the black-point fungus in the seed appeared to be about five years under ordinary granary conditions.

Diseases of seed corn.—Germination tests by the Illinois station of samples of corn shown at the Utility Corn Show at Urbana in January, 1925, showed certain common diseases to be quite prevalent even in the better class of seed corn. For example, infection with scutellum rot ranged from 0 to 27 per cent, averaging 5.03 per cent; *Diplodia zeae*, from 0 to 8, averaging 1.03; *Gibberella saubinetii*, from 0 to 9, averaging 1.68; *Fusarium moniliforme*, from 0 to 9, averaging 1.90; *Cephalosporium acremonium*, from 0 to 10, averaging 1.98; and dead kernels, from 0 to 14 per cent, averaging 2.20 per cent.

About 50 per cent of the seed corn used in Louisiana was found by the Louisiana station to be infected with *F. moniliforme* and about 30 per cent with *C. acremonium*, but neither of these appear to have any marked effect on the stand or yield nor on the suckering of the plant. The presence of suckers seemed to have no effect on the yield of the individual plants, although a better stand was maintained with plants that suckered freely. Better stands and consequently higher yields were obtained with corn that gave good results in the germination test, but the individual plants yielded no better than plants from corn which gave poor germination. Smooth ears gave better stands and higher yields than roughdent ears, and the individual plants from smooth ears produced slightly larger yields.

Corn smut.—Corn smut is becoming an important limiting factor in production in certain regions, according to studies at the Kansas station. No evidence was found of systemic development of the disease in corn plants in the field. Apparently moisture is not a controlling factor, and infection does not depend so much on the time of the season as on the stage of development of the host plant. Apparently partial control was obtained by the use of fungicidal sprays, but wherever the smut was lessened by the use of fungicides there was a corresponding reduction in yield. Planting different varieties of corn on successive dates to avoid infection gave negative results. Strains of corn showing great variations in susceptibility and resistance to smut were obtained by inbreeding.

Bacterial leaf spot of corn.—Studies of this disease by the Iowa station indicated that it is caused by an undescribed species of bacterium. The disease has a wide range of hosts, including sorghum, sudan grass, Johnson grass, foxtail and corn. Cross inoculations and cultural studies show the organism from the various hosts to be the same, although the symptoms of the disease vary somewhat with the host.

Downy mildew of foxtail.—This disease, caused by *Sclerospora graminicola*, was found by the Iowa station to be readily transmitted to corn of all types, popcorn being most susceptible. Infection took place within two days after the oospores were placed on the seed, under favorable conditions. The symptoms on foxtail and corn were markedly different in the latter, appearing as a grayish blotching and mottling, which in some cases extended throughout the whole plant, or as yellow or chloratic areas. Many of the plants died when about 3 inches tall. Infection was readily transferred to millet, French millet, and teosinte.

Smut resistance of oats.—Of 210 varieties and strains of oats tested by the Washington station, 21 were found to be apparently immune to loose smut (*Ustilago levis*), and others more or less resistant. Among the immune varieties were Markton and Red Rustproof, the latter carrying apparently three dominant factors for immunity, any one of which prevents the production of covered smut spores. The results encourage the hope that in time this and other plant diseases may be successfully controlled by the introduction of resistant or immune varieties.

Potato scab.—Studies by the New Jersey stations indicated considerable difference between the hydrogen-ion concentration of the juices of resistant and susceptible varieties of potatoes, the latter showing much higher values, indicating that resistance may be due partly to this fact. Investigations reported by the Minnesota station indicated that abundant soil moisture during the period of early tuber formation

will retard scab infection. There appeared to be a critical period for infection in the development of the tuber. Temperature did not seem to be an important factor, but the hydrogen-ion concentration was important.

Blackleg of potatoes.—Blackleg is a widespread disease of potatoes, causing serious losses both in field and in storage. It has been studied by several of the experiment stations, notably those of Maine, Michigan, and Minnesota. Recent investigations by the Michigan station identify the causative organism as *Bacillus atrosepticus*. Losses due to the disease were found to vary with the season. Cool, wet seasons appear to be very favorable to the disease and much greater losses occur during such seasons than during warm seasons of little rainfall. No resistant commercial varieties have been found. The organism overwinters in tubers left in the ground, but not in the open soil. It quickly disappears or loses its pathogenicity in the soil. It apparently can not enter uninjured roots. Investigations by the Minnesota station showed that the pathogene and bacteria of blackleg hibernate in the pupa of the seed corn maggot and are constantly in the intestinal tract of adult flies early in the spring. Egg laying is at its height at the time potatoes are being planted. Eggs are deposited in the soil by or on potato seed pieces before and after planting, as well as in the soil around the stem of sprouting seed pieces. The eggs hatch into maggots which burrow into the seed pieces, introducing the pathogene.

Stem-end discoloration of potatoes.—The North Dakota station found that stem-end discolorations are not due entirely to the Fusarium wilt fungus but are also often caused by the blackleg bacillus, and both organisms may occur in the same tuber. Many discolored tubers yield no organism. The amount of discoloration due to any one cause in a year's crop is proportional to the amount of disease in the vines in the field. Of 167 discolored tubers examined 7 per cent showed discoloration to be due to Fusarium wilt, 22 per cent to blackleg, 2 per cent to both, 10 per cent to dry rot and other rot fungi, and 59 per cent to nonparasitic causes.

Rhizoctonia disease of potatoes.—The Washington station finds Rhizoctonia to be indigenous to western soils and to persist under cultivation as a parasite on many hosts and as a saprophyte on plant remains in the soil. It considers the disease a close second in importance to the virus diseases among the troubles of potatoes. The disease attacks the plant at all stages. Direct injury is confined to the root system or other subterranean structures. Probably the most important injury is caused by death of feeding roots. Other crops following diseased potatoes are attacked and seriously injured by the disease because of the virulence of the parasite left in the soil. Selection of seed free from sclerotia of the disease and treatment of the seed with mercuric chloride have proved to be effective means of control.

Degeneration diseases of potatoes.—New symptoms of the various distinct degeneration diseases of potatoes previously described by the Maine station were studied with the result of showing variations in the response of the different diseases to leaf-mutilation inoculation, aphid transmission, and root and foliage contact infection. A third species of aphid, *Aphis abbreviata*, capable of transmitting mild mosiac was reported. Comparison of Long Island and Virginia seed potatoes indicated that a hot climate may cause degeneration of potatoes indirectly through favoring the spread of the disease, and emphasized the need for local or regional study of the potato degeneration problem.

Recognizing the extreme difficulty of identifying potato degeneration diseases because of their varied manifestations under different conditions, the Nebraska station among others has studied especially the evironmental factors masking the disease symptoms. It was observed that light, soil moisture, and soil temperature have no effect on foliage symptons. The effect of air temperature, however, was very pronounced and it is considered the most important factor in masking foliage symptons.

Selecting potatoes for seed from large hills may be unsafe practice, the Vermont station points out, because hills, commonly called "giant hills," are apt to be abnormal and produce abnormal tubers. The crop grown from such seed very generally is made up of ill-formed, spindle-shaped tubers, giving evidence of disease

Spindle-tuber disease is one of the obscure so-called virus diseases of potatoes which appears to be widespread and has been investigated by a number of experiment stations. The Nebraska station reports that it is one of the most serious potato diseases in that State, reducing the yield and lowering the market quality of the crop. It is carried over in the seed tubers and is transmitted by insects. It spreads more rapidly in irrigated lands than in

dry land fields. Environmental conditions were found to exert a marked effect on the symptoms. At high temperatures symptoms were more apparent in the plant tops and the tubers were much elongated and lighter in color, whereas at low temperatures the symptons were less apparent. High soil moisture content tended to cause tuber elongation, and heavy soils produced more spindle tubers than lighter ones. It is stated that the best methods of control now known are "to secure a lot of potatoes containing no spindletuber or as little as possible, and then to select the best type tubers for planting a seed plat isolated by at least 300 feet from any other potatoes. This seed plat should be thoroughly rogued a number of times throughout the season, removing any suspicious-looking plants that might be infected."

Disease-producing viruses in potatoes.—Viruses capable of producing disease when inoculated into other solanaceous plants were derived by the Wisconsin station from apparently healthy plants of various standard varieties of potatoes. There appear to be at least two viruses present in the plant juices. These viruses were similar in nature and properties to those of other well-known virus diseases of plants with respect to filtration, dilution, insect transmission, and resistance to desiccation, putrefaction, heat, and chemicals. Inoculated into tobacco they produced charactersitic diseases of three types—mottle, spot necrosis, and ring spot. Apparently potatoes are either true carriers of viruses or potato protoplasm is actually the causal agency of one or more of the virus diseases of tobacco and other solanaceous plants.

Early blight tuber rot of potatoes.—Several strains of the causative fungus of this disease have been found by the Maine station, which are distinct with respect to certain physiological characteristics but apparently alike as to virulence. While this was formerly considered a foliage disease, it was found to cause tuber rot also.

Disease-free seed potatoes.—The production of disease-free seed potatoes is rapidly becoming more difficult. The New York State station finds that highgrade seed may usually be obtained year after year by careful choice of planting stock, planting on an isolated plat, rigid inspection of the plat, and removal of all weakened or diseased plants. However, after following this method for five years the station found that stock which was practically free from leaf roll at the beginning of the period had 15.5 per cent of that disease at the end.

Disinfection of seed potatoes.—Tests by the New Jersey stations showed both nickel and copper carbonate to be unsatisfactory for seed potato disinfection, the former preventing germination and the latter reducing both germination and yield. The use of organic mercury dust at the rate of 4 ounces per bushel gave good control. Dust treatments after the tubers were cut caused no injury to the seed pieces.

Dusts v. sprays for potatoes.—Comparative tests of dusts and sprays on potatoes at the Michigan station indicated that spraying with Bordeaux mixture, to which nicotine was added, was more effective and economical, in a season when hopperburn was very severe, than dusting with a dry copper-lime mixture containing nicotine. There was no evidence of stimulative effect of the Bordeaux mixture.

Treatment of cotton seed for disease control.—The North Carolina station found that, while the moisture content is a factor which strongly modifies the resistance of anthracnose in cotton seed to heat, drying does not kill the organism but makes conditions more favorable for the effective action of heat. Control of the diseases without serious reduction of germination was secured by drying the seed at 60 to 65° C. for 20 to 24 hours followed by 12 hours' heating at 95 to 100°. An efficient machine for applying the treatment was devised and is described.

There is no quick means of eliminating anthracnose from cotton seed under ordinary farm conditions, according to the South Carolina station. The best treatment appears to be to delint with strong sulphuric acid, place in clean bags, and store two or three years in a dry building. A certain amount of artificial heat, as in a dwelling, may be an advantage.

Cotton root rot.—Studies by the Texas station showed that in central Texas the perennial tie-vine (*Ipomoea trichocarpa*) is the most important summer and winter carrier of cotton root rot, and successful control of the disease depends upon the eradication of this weed. More than four years of clean fallow or a system of rotation using nonsusceptible crop in connection with clean cultural practices was required to completely destroy the tie-vine. The weed carriers were found to vary in different parts of the State. Growth of the fungus was completely inhibited by a 0.2 per cent normal hydrochloric acid, 0.21 per cent normal sulphuric acid, and

5.5 per cent normal sodium hydroxide, showing it to be very sensitive to acidity although quite tolerant of basic salts.

Sunflower wilt.—The Montana station isolated the organism causing sunflower wilt, and successfully inoculated it into different parts of the plant. The organism was found to be present in the soil, which becomes progressively infected.

Sunflower rust and leaf spot.—The Minnesota station found that all of the common sunflowers are susceptible to both rust and septoria leaf spot. It was impossible to control the diseases by sprays or dusts.

Tobacco black root rot.—The supposed ascospore stage, *Thielavia basicola*, of tobacco black root rot was found by the Connecticut State station to be a fungus distinct from the common conidial stage, *Thielaviopsis basicola*, the latter rather than the former being responsible for the rot.

Root rot resistant tobacco.—The Pennsylvania station found marked differences in susceptibility to root rot (*Thielavia basicola*) of different strains, hybrids, and selections of tobacco. The hybrids Olson, Hibshman, and Leaman showed superiority over common selections of Pennsylvania Seedleaf in this respect. Hibshman has proved especially successful and popular with growers in Lancaster County. Olson appears to be well adapted to conditions in Clinton County. Root rot resistant strains of both the standup and drooping types of Burley tobacco have been found by the Kentucky station, which have proved superior to the commonly grown varieties on diseased soil both in rate of growth and quality.

Black shank of tobacco.—The Florida station found the Phytophthora causing black shank to some extent intermediate in morphology between *P. nicotianae* and *P. parasitica*. All three forms produced similar symptoms in potato, tomato, eggplant, and castor-oil plant seedlings. All commercial types of tobacco proved highly susceptible to the organism, while *Nicotiana rustica* was resistant. The minimum temperature for infection was below 20° C. Progress has been made in the development of a resistant strain of Big Cuba tobacco.

Wildfire of tobacco.—Control of wildfire of tobacco was further studied by the Wisconsin station with the result of confirming the conclusion that control is almost entirely a matter of preventing seed bed infection. It was found that the causative organism overwinters readily in the dry and dormant condition, especially in dried tobacco leaves and refuse and on seed. It may survive in the dormant state on seed as long as two years. Spread in the field is almost entirely dependent upon rainfall, especially when accompanied with high wind. Destruction of infective material, especially that from the curing shed, was found to be an effective means of controlling spread of the disease. The use of fungicides did not prove very effective. Evidence was obtained of the presence of a toxin produced by the wildfire organism, which, even in great dilution, is capable of rapidly producing chlorosis in plants.

Physiological drop of apples.—The Delaware station finds that in normal years, with trees producing a normal amount of compatible pollen, lack of pollination can not be considered as being the chief cause of physiological drop in fruits, as a majority of the flowers were found to be properly fertilized and embryo development had taken place in all specimens of dropped fruit. The dropping did not seem to be correlated with soil fertility.

Apple scab.—In studies on spore dissemination of *Venturia inaequalis* the Wisconsin station found that, in the vicinity of Madison, asci were capable of discharge under favorable conditions on May 7, 1917. The maximum content of ascospores in the orchard air was observed on May 21. The most important requisite for the discharge of the asci was the presence of an adequate supply of water. In cases where abundant asci were in condition to eject their spores in the presence of water, heavy discharge started soon after rain began and continued with continuous rain as long as the supply of ripe asci lasted, periods of very heavy discharge lasting from 3 to 15 hours. Conidia were found in the air only during the rain periods and particularly when rain was accompanied by strong wind. Germination tests showed that practically all naturally discharged ascospores were vigorously viable. Conidia germinated with much less regularity. "Infection from conidia applied in suspension in water was secured at will upon young leaves if fairly low temperatures (maximum at which infection accurred somewhat above 25° C.) were maintained. Old leaves were highly resistant to infection."

Adequate protection against apple scab was obtained by the New Hampshire station by spraying at the prepink, pink, and calyx stages only. Spraying with Bordeaux mixture only gave better scab control than using lime-sulphur only, but the russeting of the fruit was worse. Lime-sulphur solution satisfac-

torily replaced Bordeaux mixture, and under light scab infection a prepink and a,lcyx spray, or a pink and calyx spray gave adequate control.

Apple canker.—The perrennial canker of apple trees, according to the Oregon station, differs from apple tree anthracnose in at least four distinct ways: (1) It is perrennial in character, (2) it is more distinctly a wound parasite, (3) it has different shaped conidia, and (4) it reacts differently in culture media. The name *Gloeosporium perennans* is proposed as the scientific name and "perrennial canker" as the common or horticultural name. Liberal use of Bordeaux mixture, particularly spring application of Bordeaux oil, appeared to be of some assistance in checking the disease. Eradication measures include cutting out the diseased tissues; cleaning out all wounds and injuries with an antiseptic wound dressing, preferably Bordeaux paste made up in raw linseed oil; and painting them over. The only advantage in cutting out the apple blister canker as it appears is, according to the Illinois station, to eliminate the spores of the fungus so that they will not be carried to healthy trees.

Sulphur treatment of crown gall of apples.—Sulphur treatment of soils for crown gall of apple trees in nurseries may be effective in some cases, according to the Tennessee station, but the conditions under which it is most effective have not been definitely determined.

Cherry leaf spot.—Defoliation by cherry leaf spot was found by the Michigan station to lower the vigor of the defoliated trees and to reduce seriously the yield of the succeeding year's crop. Spraying with liquid lime-sulphur diluted at the rate of 3 gallons in 100, with 2 pounds or more of lead arsenate in each 100 gallons of the diluted solution, and applied (1) just after the petals drop, (2) two weeks after petal fall, (3) four weeks after petal fall, and (4) just after harvest was found to be the most effective means of controlling the disease on sour cherries.

Citrus canker.—The organism of citrus canker changes in shape and size with age, according to the Florida station. It grew best on potato glucose agar.

Citrus blight.—A definite correlation between the occurrence of citrus blight and the soil type was observed by the Florida station. It was found to be of comparatively rare occurrence on soils with good water-holding capacity. It appears to be a physiological trouble arising chiefly from a deficiency of soil moisture during the dry season of the year, and it may also result from a sudden and prolonged excess of soil moisture. No causative organism was found and no indications that the disease can be communicated by grafting. It is concluded that control should be sought through use of preventive means, such as improved cultural practices and building up the supply of organic matter in the soil.

Fig smut.—Although the fig is well adapted to a wide area in California, its culture is not so well established as that of many other fruits, because mainly of the occurrence of various forms of rotting, souring, and molding of the fruit which at times cause serious losses. One of the most serious of these troubles is, according to the California station, so-called smut due to *Aspergillus niger* which is carried into the figs by insects, especially the dried fruit beetle (*Carpophilus hemipterus*). Destruction of the insects appears to be the most promising means of control. The best methods at present known for accomplishing this consists in destroying all old fruit, fruit culls, and refuse in which insects breed. Spraying and soil fertilization were of no avail. The Black Mission and Kadota varieties were found to be much less affected by smut and similar troubles than the Calimyrna and Adriatic sorts, because their solid structure and closed eye exclude insects from the inside of the fruit.

Fig rot.—A rot of the Smyrna fig, doing much damage in California, is reported by the station to be due to a fungus tentatively identified as *Oospora verticillioides*. The fact that the trouble was found to occur only in caprified figs is taken to indicate that the source of infection is Blastophaga.

Black rot of grapes.—The primary point of new infection of black rot of grapes is, according to the Delaware station, in lesions on the first few internodes of the cane and not in leaves and rotten fruit as has previously been stated. Black rot can not be controlled unless spraying is started much earlier than is commonly recommended. The station found that the so-called "carry-over" lesions in grapes contain several diseases other than black rot. Anthracnose (*Sphaceloma ampelinum*) and bitter rot (*Melanconium fuligineum*) were found carrying over in the first few internodes of the canes. Evidence was also found of the occurrence of Reddick's dead arm disease (*Cryptosporella viticola*) and also of *Pestalozzia uvicola*, a European grape rot, in carry-over lesions on the canes.

Root rot of grapes.—A mushroom root rot of grapes, prevalent in the Ozark region, was found by the Missouri sta-

tion to be due to *Clitocybe tabescens*. The disease is associated with lands which formerly were covered by hardwood timber, especially oak. It appears to be practically unknown in strictly prairie soils and in old land, except at the margins in close proximity to timbered lands. It attacks grapevines and fruit trees chiefly in places where the soil is poorly drained. Drainage is therefore considered the most important remedial measure.

Pear blight.—Pear blight is, according to the Oregon station, probably the most destructive disease of fruit trees in America, attacking blossoms, shoots, large branches, trunks, and roots. The best varieties of pears are susceptible to the disease. The most successful method of combating the disease yet suggested, viz, to cut out promptly all the affected parts and disinfect the wounds, merely reduces the losses; it does not entirely prevent them. Of numerous varieties and species tested by the station, only *Pyrus ussuriensis* showed resistance in the young shoot and *P. calleryana* in the trunks and roots. The first is of little or no value on account of its slow growth. The latter appears promising as a rootstock. It is suggested that "losses from trunk and root blight can be largely prevented in the newer orchards by planting a resistant variety like Old Home on a resistant rootstock like *P. calleryana* or Ba Li Hsiang and topworking them when 3 or 4 years old with the desired commercial variety."

Chlorosis of pineapples and other plants.— Manganese chlorosis of pineapples, a trouble which at one time seriously menaced the pineapple industry of Hawaii, was found by the Hawaii station to be due to the depressing effect of manganese, which occurs in unusual quantity in many Hawaiian soils, on the assimilation of iron. It was shown that the trouble can be overcome by spraying the plants with a solution of iron salts. The treatment is now in general use in over half of the pineapple fields of Hawaii. The Rhode Island station found evidence that chlorosis sometimes following heavy liming in that State is due to need for manganese. Chlorosis of spinach, oats, beets, beans, and peppers was reduced or prevented by applications of soluble salts of manganese. Direct correlations were found between the soluble manganese content of the plants and both manganese applications and the correction of chlorosis.

Raspberry anthracnose.—Anthracnose of the raspberry was controlled by two seasonal applications of lime-sulphur, in experiments at the Illinois station. Two sprays, one a delayed dormant application as the leaflets were opening and the other a pre-bloom spray applied a week before the bloom, were effective. The addition of a casein-lime preparation gave somewhat better control. In experiments at the New Jersey stations the disease was controlled by four applications of lime-sulphur which gave better results than Bordeaux mixture. The addition of calcium caseinate to lime-sulphur increased its fungicidal value.

Virus diseases of the raspberry.—The Michigan station reports at least five raspberry diseases of the virus type in the State. Two species of aphids, *Amphorophora rubi* and *Aphis rubiphila*, were found to be transmitting agents. Roguing out diseased plants was effective with some of the troubles but of doubtful value with others. The rate of spread of raspberry mosaic, under the same climatic conditions, was found by the New York State station to vary greatly according to the variety. The rate of spread also varied in different sections of the State, due probably to the relative abundance of aphid carriers. Roguing as a means of control has yielded excellent results.

Yellows-resistant cabbage. — Continuing work in selecting yellows-resistant second-early varieties of cabbage, the Wisconsin station found that desirable resistant types may be obtained from any of the standard varieties. Selections of All Head Early and Glory-Copenhagen types are approaching a stage where they will be of commercial value.

Wire stem of cabbage.—Wire stem due to *Corticium vagum*, which is the cause of widespread and serious losses, has been exhaustively studied by the New York Cornell station, which finds that the strain of the organism causing the disease is physiologically distinct from that causing lesions in potato stems. "The minimum and maximum temperature for the growth of the fungus in pure culture are approximately 9 and 31° C. The optimum is not sharply defined, but it lies between 22 and 26°. The fungus exhibits a wide pH range for growth, the minimum being approximately 2 and the maximum above 10.4. The optimum is about 6.2. Practically any combination of soil temperatures and moistures favorable for the growth of the host is favorable for the growth of the fungus and for the development of wire stem. Consequently, no changes in the environmental conditions will control the disease."

Composition of diseased celery leaves.— Celery leaves affected with *Cercospora apii* and *Septoria apii* were found by

the Michigan and New Hampshire stations to contain less nitrogen than healthy leaves. The nitrogenous compounds of the diseased leaves contained more ammonia, humin, and protein and less hydrolyzable matter, acid amide, and basic and nonprotein nitrogen than healthy leaves. Nitrites were found to be present in the diseased leaves.

Downy mildew of cucumbers. — Spraying and dusting experiments by the Florida station showed that fungicides which contained copper were superior to those not containing it. Fungicides applied in the form of dust gave almost as good control as did liquid sprays. The cost of the dust, however, when both material and labor were considered, was about twice the cost of the liquid spray.

Toxins in onion juice.—Toxins of two general kinds, volatile and nonvolatile, were found in onion juice by the Wisconsin station, cooperating with the Department of Agriculture. The former decreased in storage and sprouting. Experiments with various onion bulb parasites showed in general that the reaction of each fungus followed the same trend with the dissolved as with the volatile toxins, and indicated that the host toxins may be one of the numerous factors which determine the degree of parasitism attained by a given parasite.

Onion smut immunity.—Of 39 species of Allium tested by the Massachusetts station 8 seemed to be immune to onion smut (*Urocystis cepulae*) and 31 showed varying degrees of susceptibility. Thirteen species appeared to be very susceptible, and in the same class as the common onion, of which 54 varieties were examined without finding evidence of any considerable resistance to smut.

Root rot of peas.—*Aphanomyces euteiches* was found by the New Jersey stations to be the causative organism of one of the major root rots of peas in the State, pure culture inoculations producing the typical symptoms. The zoospores remained active in water for five to seven days and were capable of causing infection at any time during this period; but there was little migration of the zoospores in the soil, tests showing that they were unable to traverse a distance of one-half inch, and there was very little spread of the disease in the field. A soil moisture content of 30 per cent saturation was found to be close to the minimum for infestation, higher percentages of soil moisture being more favorable. Of a large number of legumes inoculated with this organism, garden and Canada field peas were found to be very susceptible and hairy vetch slightly so. Other legumes tested as well as corn were not attacked.

Sweet-potato scurf.—Tests by the New Jersey stations showed that applications of from 300 to 600 pounds of sulphur per acre were effective in reducing scurf infection. In one test the disease was almost completely controlled by the use of about 600 pounds per acre, although the yield was reduced about 16 bushels. The production on untreated plats and those receiving 300 pounds of sulphur was practically the same. The results showed the beneficial effects of sulphur in reducing the disease in light soils. The fungus causing scurf was found to spread gradually on the stem of the plant. Early harvesting on severely infected areas reduced the number of black stained potatoes. Inoculation tests showed that infection will not take place in presence of high acidity, the point of infection being somewhere between pH 4.5 and 5.

Sweet-potato pox.—In studies by the New Jersey stations on the relation of soil moisture to this disease it was found that with from 4 to 6 per cent moisture, based on the water-holding capacity of the soil, the potatoes and roots were severely poxed, and on most of the plants the roots were completely blackened. With from 8 to 10 per cent moisture the potatoes were not attacked, but the roots showed many poxed spots. With from 12 to 16 per cent moisture the infection was very slight, and with 18 per cent, which was the water-holding capacity of the soil, there was no infection of the roots. The results showed the importance of maintaining a favorable soil-moisture content, especially during June and July when the most severe attacks occur. The application of from 200 to 300 pounds of sulphur per acre annually was sufficient to control the disease. The causative organism was not obtained in pure culture.

Nailhead rust of tomatoes.—The Florida station found that copper sprays and dusts were superior to those not containing copper for the control of nailhead rust of tomatoes. Homemade Bordeaux mixture, made either with rock or hydrated lime, gave the best control. Some commercial copper sprays recently put on the market proved to be of no value. In a varietal resistance trial the Globe proved to be the most resistant.

Tomato wilt.—The Kansas station found the most practicable effective method of controlling tomato wilt, due to *Fusarium lycopersici*, to be the growing of resistant varieties. "Six varie-

ties introduced into the State for trial purposes and one developed at the station have proved wilt resistant, commercially desirable, and climatically adapted to Kansas. They are Louisiana Red, Louisiana Pink, Marvel, Norton, Norduke, Marvana, and Kanora."

Disinfection of tomato and pepper seed.—Seeds of tomato and pepper were treated with commercial disinfectants for periods varying from 5 to 25 minutes, in experiments at the Florida station. Five minutes' treatment reduced the germination of the seed, the injury being increased as the time was lengthened. With 25 minutes' treatment the amount of injury was 15 per cent. Ten minutes was found sufficient for disinfection, and this is advised, allowing for a 10 per cent injury. The treatment was found to kill the weaker seed and eliminate the weaker plants in the seed bed, thus proving beneficial.

Pecan scab.—The organism of pecan scab, *Fusicladium effusum*, was found by the Florida station to grow best at 25° C. and slower at 15 and 30°. Inoculations took from 5 to 21 days to show symptoms. The disease was found to be carried over in the old husks and twigs, and infection in the groves always became worse after rains.

Coconut bud rot.—Coconut bud rot has been found by the Porto Rico station to be associated with a species of Phytophthora. The period of incubation may vary from two to nine months, depending upon weather and other conditions. Attempts to transmit the disease through diseased roots gave negative results.

Fusarium disease of vanilla.—Fusarium disease of vanilla was found by the Porto Rico station to spread rapidly through the soil and quickly attack and kill aerial roots of vanilla plants. No wilting was observed as in the case of banana wilt caused by *F. cubense.*

Phytophthora disease of tulips.—A hitherto unreported tulip disease due to *P. cactorum* was found by the Illinois station to be common in moist, ill-ventilated situations. It was more common on double than on single blossoms. The iris was also found to be susceptible to inoculation of the disease. The only suggestion made as to prevention is to avoid situations that are especially humid.

Taxonomy of Fusarium.—The fundamentals of taxonomic studies and classification of Fusarium, with special reference to the identification of species, were defined and formulated in a report published during the year by the plant pathologist of the Tennessee station cooperating with other specialists.

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Color pigments in Fusaria.—Hydrogen-ion concentration of the culture media controls the develop ment and determines the color of pigment in Fusaria, according to investigations reported by the California station. The pigments produced were of two kinds, diffusible and nondiffusible; that is, pigment retained within the cell and pigment escaping through the plasmatic membrane and cell wall. Pigments were produced by practically all of the species experimented with in dextrose solutions at hydrogen-ion concentrations between pH 3.5 and 5.5.

Physiologic forms of Helminthosporium.—At least 37 physiologic forms of Helminthosporium have been found by the Minnesota station. Some of these mutate readily in culture media, the mutants differing considerably from the parents both morphologically and physiologically, and varying in virulence. The organism lives in the soil year after year, the spores being very resistant. They germinate readily only in the presence of certain plant tissues. Cereals proved to be more susceptible when somewhat weakened; consequently good cultural practices aid in reducing losses. *H. gramineum* was found to be severe on barley, especially the early sowings, because soil temperatures of from 10 to 12° C. are most favorable for infection.

Liquid v. dust sprays.—The relative value of liquid and dust treatments has been the subject of much investigation by the stations, with somewhat discordant conclusions. The New York State station, comparing liquid Bordeaux mixture with copper-lime dust of practically the same composition as the liquid spray on potatoes, found that in seasons when blight and leafhoppers were both fairly abundant the Bordeaux spray gave far more satisfactory control than the copper-lime dust, even when the dust was used twice as often as the spray, and concludes that for maximum yields, and probably for maximum net profits, spraying should be given the preference over dusting if adequate facilities for spraying are available.

ENTOMOLOGY

Alfalfa weevil.—Charting the climatic conditions affecting the distribution of the alfalfa weevil (*Phytonomus posticus*) in the United States, the Montana station found the areas of optimum and limiting conditions to agree in all essential particulars with the present progress of infestation. The station concludes that it is "highly probable that the alfalfa weevil has been imported into this country many times and

that it also has often been shipped out of the quarantine areas into other parts of the country, but that it has failed to establish itself except where it was placed in a region of favorable climatic conditions." Two limiting factors are temperature, applying largely to the hibernating adults, and humidty, which applies to the larva and its fungus enemies. The Idaho station found that the activity and control of the alfalfa weevil is affected to a significant extent by seasonal variations. In the late, cold spring of 1923, with excessive moisture in May and June, early maturity was retarded, but the period and extent of injury was increased. In 1924 conditions favored early maturity and an extremely short feeding period.

The alfalfa weevil has become one of the most destructive and important insect pests in Nevada, but the Nevada station finds that it can be controlled by spraying with arsenical poison applied just as the alfalfa begins to look grayish. Spraying was found to be more effective than dusting. The introduced parasite, *Bathyplectes curculionis,* has become common throughout the weevil infested territory and often kills the majority of the weevil larvae.

European corn borer.—The New Hampshire station found that under New Hampshire conditions about 60 per cent of the borers exhibit two generations, but only a small percentage of the second generation is able to overwinter successfully, and the survivors develop into adults of small size capable of producing a relatively small number of eggs. Apparently this is a limiting factor in relation to normal increase of this species under field conditions.

Cornstalk borer.—The New Hampshire station noted that in the early stages the larvae of this insect appear to prefer the grasses. There may be from seven to nine instars. Twenty-two different host plants have been observed under field conditions. Some females are able to deposit eggs one day after emergence. Some parasites were found.

Cotton-boll weevil.—Boll weevil injury appears to be a variable factor in cotton production in the Piedmont region of South Carolina. For this reason the South Carolina station finds that early application of poisons may not be profitable in some seasons. In normal seasons the main reliance should be placed upon late applications. Usually these applications should be started as soon as boll-weevil injury is observed on as many as 10 per cent of the squares of the plant. The Florida stripping method did not give profitable results under the conditions of the South Carolina experiments.

Dusting with calicum arsenate did not give satisfactory control of the boll weevil in Oklahoma. The molasses arsenate treatment gave better results. Use of the Florida method resulted in a loss. The use of a cage in which punctured squares and forms are placed and which allow the parasites but not the weevils to escape is recommended, as is complete final picking of cotton as early in the fall as possible and the immediate destruction of the plants unless they have already been killed by frost.

The cotton hopper.—Further studies by the Texas station of the cotton hopper (*Psallus seriatus*) showed it to be a large factor in producing the blasting of small cotton squares. Eggs were found on the tender growth of the cotton plant, on five species of Croton and on two of Monarda, and also on remnants of cotton stalks which were broken up and plowed under during the winter and brought to the surface by cultural operations in the spring. There was no migration from Croton weeds to cotton. Overwintered eggs first begin to hatch about April 1 and hatching continued until the middle of May. The maximum number of eggs, which were laid singly, during the life of a pair was 34. The average egg stage was 7.8 days, and there were five instars. In summer complete development from hatching to the adult stage required from 7 to 10 days. Good control was obtained with sprays containing sulphur.

Leafhoppers and curly leaf of sugar beets.—Sugar beets are subject to severe damage as a result of insect attack. The Utah station records a list of 12 or more insects preying upon this crop. One of these, the leafhopper or white fly, is responsible for transmission of the very destructive curly leaf disease, which has resulted in the abandonment or removal of sugar factories in California, Idaho, and Oregon. The loss to farmers in the Bear River Valley in 1924 is reported to have been $1,500,000.

Wheat stem maggot.—The wheat stem maggot (*Meromyza americana*) is, according to the South Dakota station, widely distributed in that State wherever certain native grasses or cultivated cereals are found. The station found that the adult flies appear about the first of June and that there may be three generations a year, although in some cases only two generations are produced. The maggot was found to be heavily parasitized, but parasites apparently can not be relied upon to control the

pest. Such control measures as rotation of trap crops, destruction of volunteer grains and grasses, and late planting of fall grain are recommended.

Field cricket.—A study of the natural enemies of the field cricket by the South Dakota station showed these to include 2 hymenopterous egg parasites, 2 species of nematode worms, 1 species of gregarine, 1 Tachnid fly, and several mites, all attacking the nymphs or adult crickets, which are also attacked by several predacious animals, but these are not sufficient to hold the crickets within bounds. The most satisfactory means of control was destruction of the eggs by disturbing the soil in which they are laid during the late summer and fall. An exposure of one-half hour killed the eggs. Poison bait gave a maximum kill of only 50 per cent.

Cyanide for grasshoppers.—Two hundred pounds of granular calcium cyanide per acre, distributed over the ground where young grasshoppers congregated, gave a 100 per cent kill in tests made by the Washington station. It gave best results when applied in the evening or during cool, cloudy days.

Codling moth.—The New Jersey stations found that the amount of injury done to the apple by the codling moth under arsenical treatment varies, within limits, inversely as the quanity of arsenic applied per tree per treatment, inversely as the constancy with which the coating is maintained during the periods of larval entry, and directly with the concentration or density of the codling moth infestation, the concentration being the most powerful factor. Dust treatments were less effective and somewhat more expensive than liquid treatments.

The first brood of the codling moth is by far the most important in commercial apple growing, according to the Virginia station. Failure to control the first brood is normally followed by continuous egg laying and hatching from late June or early July to late September. Timely and thorough spraying is therefore necessary. In orchards where large numbers of worms winter or where the proportion of wormy apples at picking time amounts to about 5 per cent of the crop, four lead arsenate sprays are recommended as follows: (1) When most of the petals have fallen; (2) about 3 weeks after petal-fall stage; (3) about 5 weeks after the petal-fall stage; and (4) about 10 to 11 weeks after the petal-fall stage.

Oil emulsion for San Jose scale.—Homemade lubricating oil emulsion proved, in experiments by the New York State station, to be an efficient insecticide for the control of San Jose scale and was successfully used to combat this pest in old apple orchards where it had been difficult to secure satisfactory protection with lime-sulphur solution of standard strengths.

Rosy apple aphis.—Delayed dormant applications of dust mixtures containing nicotine did not give satisfactory control of the rosy apple aphis, in experiments at the New York State station, but were effective if used not much later than when the pink color of the more advanced blossom clusters was first observed. In addition to sufficient dosage, other favoring conditions were fairly high temperatures, freedom from foliage moisture, and little or no air stirring. Applications of dust mixtures during the pink period and calyx period invariably proved ineffective.

Fruit-tree leaf roller.—The Pennsylvania station found that the habits of the red-banded leaf roller (*Eulia velutinana*) differed widely from those of the so-called fruit tree leaf roller of more northerly apple growing regions, and that the recommendations for the control of the latter were not applicable in Pennsylvania. In a study of the life history, habits, and control of the red-banded leaf roller, three complete generations in a season were recorded. A number of parasites were reared from the pupae. Arsenate of lead applied at the pink stage at the end of June or early in July and at the end of August or beginning of September poisoned the young larvae of the first, second, and third generations, respectively, and prevented injury to the foliage and fruit.

Methods of control of the fruit-tree leaf roller by use of oil emulsion sprays were worked out by the Idaho station and successfully applied in practice. Lubricating oils proved but little more effective and were more expensive than neutral oils for this purpose. The emulsion spray controlled San Jose scale as well as roller.

The most promising means of controlling the fruit-tree leaf roller found by the New York State station was the application of oil preparations at the period when the eggs were about ready to hatch and treatment of the trees with arsenicals when the young caterpillars first appeared, followed by applications at intervals of a week or 10 days throughout the hatching period. No appreciable improvement in the killing efficiency of common spray mixtures resulted from the incorporation of spreaders, such as glue, calcium caseinate, or soaps.

Oyster-shell scale.—The New York Cornell station concludes that there are

two distinct forms of the oyster-shell scale, one occurring especially on the apple, the other on the lilac, the one on the apple being probably the older. The evidence is not sufficient to determine whether the differences are great enough to warrant the erection of a new species or only of a new variety from the form on lilac.

Green citrus aphid.—The Florida station found that from five to seven days are required to complete the nymphal stage of the green citrus aphid. Adult females produced on an average of five young per day. The most important hosts, in addition to citrus, proved to be pears, Mexican tea (*Chenopodium ambrosoides*), fireweed (*Erechtites hieracifolia*), and cudweed (Gnaphalium). A predator, the blood red lady beetle (*Cycloneda sanguinea*), was found to eat on an average 16 aphids per day. A number of other species of lady beetle were observed eating the aphids, and syrphus flies were also predators. These predators, however, were not very efficient in controlling outbreaks when conditions were favorable for rapid aphid multiplication. Lime-sulphur and the oil emulsions were effective, especially with a 1 to 800 addition of nicotine sulphate. Dusting with 3 per cent nicotine sulphate-lime dusts was effective in a quiet atmosphere or under tents. Dipping affected twigs in a solution of soap and tobacco was effective on young trees early in the season.

Plant bugs on citrus.—In experiments by the Florida station a trap crop of Crotalaria gave almost perfect control of plant bugs in a citrus grove, provided there were green pods on the Crotalaria.

Control of cranberry insects.—The New Jersey stations found that the cranberry girdler (*Crambus hortuellus*) could be killed by September flooding without serious damage to the crop of that or succeeding years. This flooding also controlled the blossom worm (*Eniglaea apiata*). Keeping a coating of lead arsenate on the cranberry vines from July 1 to September 1 not only did not injure the vines but gave a 10 per cent increase in yield, perhaps due to the destruction of some obscure cranberry feeders. Application of a mixture of arsenate of lead and resin fish oil soap burnt the foliage, but lead arsenate alone did not.

Dusting versus spraying for grape rootworm.—Dusting did not prove as effective as spraying for the grape rootworm, in experiments at the New York State station. In view of these results and until more efficient dust preparations which will stick to grape foliage have been found, grape growers are urged to use homemade Bordeaux mixture with lead arsenate.

Control of oriental peach moth.—The Connecticut State station obtained some reduction of injury by the oriental peach moth by spraying with nicotine solution in June to kill the eggs and by dusting with lead-arsenate-sulphur dust. Calcium fluosilicate compound and sulphur-lead-arsenate dust had considerable effect in preventing entrance of newly hatched larvae into the fruit. Bait pans containing molasses and yeast caught large numbers of moths.

A serious outbreak of the oriental peach moth in New Jersey in the summer of 1923 led to a special State appropriation to the New Jersey stations for study of the insect with a view to finding effective means of control. There were found to be three full generations and a partial fourth in the region of New Brunswick, that is, a portion of the larvae of the third brood remained in their cocoons for the winter and did not change into pupae and emerge as adults in 1924. Fall applications of paradichlorobenzene were found to be effective in killing the larvae of the insect cocooned on the trunks of the trees at or near the surface of the ground. Cultivation in April, at least 4 inches deep, killed 100 per cent of the overwintered larvae and pupae on the ground above the trees. Forty per cent nicotine spray was also effectively used.

Control of pear psylla.—In experiments at the New York State station, lime-sulphur showed decided ovicidal properties in case of the pear psylla. Spray mixtures gave better control of the nymphs than dust mixtures, lime-Bordeaux mixture containing nicotine being best. For control of te hadults a calcium cyanide dust or a 2 per cent nicotine-lime dust was effective.

Plum aphis.—Studies by the California station of the life history of the mealy plum aphis indicated that in most instances the insect does not winter in the egg stage on prunes and plums but migrates from tules and reed grasses to the orchards in the spring and back again in the fall. Soap sprays gave best general control when thoroughly applied.

The strawberry root louse.—The strawberry root louse (*Aphis forbesi*) is widespread, although not highly injurious in Tennesee, according to the Tennesee station. It passes the winter in the egg stage in the pedicels of the plants, beginning to hatch about February 15. It is rarely found on the roots. Increasing the daily light exposure delayed the

appearance of the true sexes and prolonged the period of viviparous reproduction. "It is possible that a combination of long days and a temperature of 50° F. or higher might have sufficed to keep the sexes from appearing." Among the more important natural enemies noted were a small syrphid (*Paragus tibialis*), a Braconidae (*Diaeretus fuscicornis*), and several Coccinellidae and Chrysopidae.

Low temperature control of bean weevil.—Temperatures below −10° C. for a period of 12 hours proved fatal to all stages of the bean weevil (*Bruchus obtectus*), in experiments reported by the Minnesota station. The growth of the insect in beans was shown to be materially retarded by storage in temperatures even as high as 64° F. The capacity of the weevil to resist low temperature was found to be limited by the length of time it could remain in the supercooled condition. This varied with the stage, active adults being least resistant and eggs most resistant. The electrothermal method did not give the true freezing point because of radiation and injury of the insect. A modification of the method which did not involve injury was devised and tested.

Generation of the pea aphis.—Nineteen generations of the pea aphis were raised during one year by the Kansas station with peas as the host plant and 21 generations on alfalfa. The age of the female when the first young were produced was 8.3 days on alfalfa and 8.9 days on peas. The length of the reproduction period was 10.8 days on alfalfa and 5.4 days on peas. The total number of young produced was 41 on alfalfa and 19.7 on peas, and the length of life on alfalfa was 21.3 days and on peas 14.5 days. In the fields the aphids were found to reproduce rapidly in March. They became scarce in early June and remained so during the summer until September.

Striped cucumber beetle.—Two generations of this beetle occur in Iowa, according to the Iowa station. A few adults were found beneath rubbish in April, evidently having wintered over in this stage. Overwintering females were found to deposit on an average 230 eggs and the adults of the summer generation began to emerge July 17, the females of this generation depositing an average of 327 eggs. Gypsum-calcium-arsenate dust gave the most satisfactory control, the first application being made when the seedlings started to break through the soil. From 8 to 12 dustings during the season were necessary.

Control of the squash-vine borer.—Neither calcium cyanide nor trap crops proved, in experiments at the West Virginia station, so satisfactory as the combined nicotine-lead-arsenate spray in controlling this insect.

Cyanide for nematodes.—Satisfactory results in the control of nematodes were obtained by the California station with calcium cyanide drilled in the furrows as the ground was plowed, at the rate of 600 pounds and upward per acre. The cyanide had a marked stimulating effect on tomatoes grown on treated soil.

Pale western cutworm.—The Montana station found that 90 per cent of the eggs of the pale western cutworm were laid upon stubble fields just cut, and on these the worms were very abundant in the spring. If such fields were plowed in the spring and planted to grain the crop was practically destroyed, but if the land was summer fallowed 75 per cent of the worms were destroyed. The worms were observed to feed on rabbit brush, Russian thistle, and goldenrod before laying eggs.

Coconut scale control.—Active measures to control the coconut scale, a severe outbreak of which had occurred on the island, were taken by the Guam station and the island authorities. Cleaning up and spraying gave good results, but natural enemies appear to offer the most promising means of control. Three important natural enemies have been found in the island, the most promising being a black ladybird, *Cryptogonus orbiculus nigripennis*, and others are being introduced.

Mealy bug on catalpa.—The mealy bug (*Pseudococcus comstocki*) is reported by the Virginia station to be a serious pest of the umbrella catalpa, marring its appearance and weakening its vitality and growth. Most of the injury is done by the third generation in late August and September. Pruning back severely, thoroughly cleaning the trees and burning the rubbish, and spraying with lime-sulphur or oil spray in the dormant season are suggested as means of control.

Spruce budworm on jack pine.—This insect although morphologically indistinguishable from the budworm on spruce and fir appears to be a distinct biologic species, according to the Minnesota station. In the region of infested jack pine the spruce and fir are not affected, and in the regions where spruce and balsam have been destroyed the adjacent jack pine stands are not infestep

Leaf-mining Diptera.—A monograph with extensive bibliography on the leaf-

mining Diptera of North America, representing an exhaustive study of the group, was issued by the New York Cornell station during the year. This bibliography brings together for the first time many scattered notes on the various species of dipterous leaf miners and summarizes the work of several years in both field and laboratory on their life histories and habits. The economic importance of the leaf miners is recognized chiefly by such forms as the beet leaf miner, the chrysanthemum leaf miner, and the box elder leaf miner. The Diptera are represented by 6 leaf-mining families and 11 leaf-mining genera in North America, and a number of these genera are entirely of the mining habit.

Control of the boxwood leaf miner.—Experiments by the Maryland station showed that the boxwood leaf miner can be controlled cheaply and effectively by spraying with a stock food molasses diluted 1 to 4 parts of water with the addition of nicotine sulphate at the rate of 1 part to 500 or 600 parts of the diluted spray material. The value of the spray was increased by covering the sprayed plants during rains with muslin or canvas.

Nicotine carriers.—The efficiency of nicotine insecticides was found by the New Jersey stations to be increased by mixing them with carriers made up of 25 per cent finely ground dolomite and 75 per cent hydrated lime. In such carriers there is a rapid volatilization of nicotine at 70° F.

Chloropicrin as an insecticide.—Chloropicrin alone or in combination with carbon tetrachloride was found by the Minnesota station to be very effective in fumigating upholstered furniture infested with insect pests. Chloropicrin and carbon tetrachloride were used as a localized fumigant in flour mills with very good success. Houses newly infested with clothes moths and black carpet beetles were freed of such pests by one treatment with chloropicrin and carbon tetrachloride.

Spreaders.—No definite proportional relationship was established between the suface tension values of spreader solutions and the observed spreading properties of the different substances, in experiments reported by the Oregon station. "Of the materials tried, water-soluble protein substances gave best spreading at lowest concentration for the greatest number of surfaces tested. Skim milk, neutralized with hydrated lime, and certain other milk products appear to be the best material for practical purposes. The concentration of a spreader solution that will give best results depends upon a number of variable factors, such as the type and age of the surface to be sprayed, the force used, and climatic conditions. The amount of lead arsenate that adheres to the leaf surface is approximately the same when a spreader is added as when one is not."

Fluosilicate as an insecticide.—Sodium fluosilicate has been found by the Tennessee station to have certain advantages over arsenicals as an insecticide, namely, it is cheaper, it acts as a contact as well as stomach poison, it kills more rapidly, it is not poisonous to human beings, and it is effective against a wide range of insects, such as chicken lice, roaches, potato beetles, Mexican bean beetle, and striped cucumber beetle. It has the disadvantage of having a very high density, 30 cubic inches to the pound, whereas the best results in dusting are obtained with materials having a volume of 80 cubic inches to the pound. It is obtained in quantity as a by-product in the manufacture of acid phosphate and promises to be a competitor of the arsenicals. The foliage injury is negligible if the material is mixed with lime and used as a dust.

Blister beetles attacking various farm or garden crops may, according to the Arkansas station, be killed by dusting with a mixture of equal parts of sodium fluosilicate and hydrated lime, or with calcium fluosilicate. Since the beetles usually feed in swarms, it is easy to cover a large number of them with a relatively small quantity of the insecticide. Sodium fluosilicate mixed with an equal quantity of hydrated lime and calcium fluosilicate may be applied with safety to tomatoes, potatoes, soy beans, and alfalfa.

Oil sprays.—The Washington station found no important difference in the killing rate of oils of similar boiling range from petroleum stock of asphalt and paraffin bases. The middle of the lubricating oil fraction seemed to be the most effective. The viscosity of an oil appeared to have only an incidental relation to its insecticidal effect and therefore little benefit is to be expected from the addition of kerosene to a lubricating oil.

Xanthates as soil fumigants.—The California station found that xanthates may be used alone as a soil fumigant, but are most effective in an acid medium in which they are converted into xanthic acid, which decomposes in alcohol and carbon bisulphide. The rate of decomposition can be regulated by adding in full or in part the amount of acid salts necessary to neutralize the alkaline

base of the xanthate. This makes possible a quick fumigating action when first applied and a slow subsequent release of carbon bisulphide, which is desirable for insects or nematodes that may be present in a resistant stage when the first application is made. Calcium phosphate and sulphur were found especially valuable for the neutralization of the xanthate.

APICULTURE

Queen bees. — Observations by the Texas station indicated that the earliest stage at which queens begin the laying of eggs is 4 days and the latest 18 days, the normal being 10.9 days. This indicates that if the queen is not laying on the eleventh day she should be replaced. The value of wholesale requeening every year was indicated.

Sirup for winter feeding of bees.—By the use of commercial invertase the Minnesota station found it feasible to invert sucrose solutions of concentrations up to 75 per cent, the sirup being superior to ordinary sucrose sirup for feeding bees in the fall, having the same concentration as honey, whereas sucrose sirup is more dilute. It is also more wholesome to the bees than sucrose.

Brood rearing of bees.—The peak of brood rearing was found by the Kansas station to occur about the first week of May, with a possible second peak later if the colony is plentifully supplied with food and the temperature is favorable. There was an inverse correlation between the rate of brood rearing and the honey flow. Brood rearing was found to begin and end in response to a temperature stimulus. A direct correlation was found between the supply of food and the rate of brood rearing before the honey flow started.

Bee parasites.—The North Dakota station found a previously unreported dipterous parasite of adult honeybees belonging to the family Conopidae. It also attacks bumblebees and other wild bees. As yet it does not appear to be very serious but may become so. Dead bees were often found in colonies where the parasite had gained a foothold.

ANIMAL PRODUCTION

FEEDS AND NUTRITION

Feed value of corn cut at different stages.— In a study of the composition of corn at different stages of growth, reported by the North Dakota station, it was found that "in the ear and fodder the greatest production of dry matter and its several constituents was either reached or approximately reached at the glazed stage. This evidence, together with the observations that after the glazed stage there was a large gain in the daily increase in the dry matter content and in the mechanical loss of dry matter of the stover, indicates, as far as production of feed is concerned, that the corn plant may be considered mature at the glazed stage." (See also p. 21.)

Calculating rations.—Various methods of calculating rations for farm animals have been proposed and used from time to time. One of these is the energy-production coefficients method proposed by the Texas station and based upon the work of Kellner, Armsby, and others. A recent bulletin of that station gives the energy-production coefficients for ruminants of a large number of American feeds, as well as the digestion coefficients from which they were derived by factors varying with the nature of the feeds.

Computing net energy of feeds.—The Pennsylvania Institute of Animal Nutrition contributed an improved method of computing net energy values of feeding stuffs, which presents certain advantages over earlier methods used by the institute. The new method involves the separate determination (1) of the net energy required for maintenance, (2) of the gain of energy by the animal, and (3) of the heat-increment value of the feed. In the method the maintenance requirement of net energy is obtained by subtracting the computed heat increment, due to the consumption of the feed, from the heat production of each period, in accordance with the principles outlined by Armsby. To this is added the gain of energy by the animal in each period, as obtained by subtracting the total heat production from the total metabolizable energy, and the result represents the total net energy of the ration, from which the net energy value of the feed is computed.

Energy value of alfalfa hay.—The gross energy value of alfalfa hay per pound of gain in sheep was found by the Illinois station to average 2,596 calories. After deducting the maintenance requirement from the total intake of alfalfa hay it was found that the net energy value of the hay consumed above maintenance averaged 32.6 therms per 100 pounds, which compares well with that given by Armsby for alfalfa hay as detemined with steers, using the respiration calorimeter.

Vitamin requirements.—Results of investigations reported by the Minnesota station indicate (1) that another or other vitamins than B and C are required for growth, (2) that the hitherto unknown factors reside in natural

foods, including milk and its unpurified constituents, and (3) that the functions of reproduction and lactation each demand either special combinations of the known biologial food units, or specific units of a vitamin nature. The fact that second generation rats were reared and reproduced normally on a synthetic diet supposed to lack the fertility vitamin raised some doubt as to the existance of such a vitamin. Great difficulty was encountered in successfully weaning the young unless milk was added to the mother's food while nursing her young, supporting the belief in the existence of a special factor or special factors necessary for normal lactation in this animal.

The existence of a "fertility" factor in the absence of which degenerative changes take place in the testes and fertility is impaired despite excellent somatic growth is indicated by experiments with rats at the Connecticut State station. The addition of lettuce to the basic ration prevented the testicular degeneration, the effect of the lettuce being due to its richness in the antisterilty vitamin E. The presence of this vitamin seems necessary for normal reproductive functions and germ cell maturation

Action of indolinones on polyneuritis.—A study by the Minnesota station of beta-methyl and beta-propyl indolinones as to their action on polyneuritis in pigeons showed that neither compound was able to protect the birds against loss of weight on a polished rice diet or against the incidence of polyneuritis. Beta-methyl indolinone had a slight curative effect. Thyroxin, an indolinone-like compound, failed to protect, and pilocarpine hydrochloride had no preventive properties.

Nitrogen metabolism of molting fowls.—The Nebraska station found wide variations in the nitrogen eliminated by birds on a nitrogen-free diet. Molting caused great irregularities in the nitrogen metabolism of fowls. The addition of cystine markedly increased the utilization of a casein ration by molting birds.

Mineral requirements.—The mineral requirements of farm animals have been the subject of investigation by many of the experiment stations. The matter is of special importance in the case of growing and gestating animals and in dairy cows, in which bone building and milk production make the demand for mineral matter particularly great. Deficiency of mineral matter is often the cause of depraved appetite, leading to bone chewing and similar habits which may in time lead to disease. The so-called loin disease of cattle reported by the Texas station appears to be an example of this and may apparently be corrected by insuring an ample supply of mineral matter in the feed of the cattle. (See also p. 55.)

The modern dairy cow, as the Michigan station points out, "is a highly specialized machine for the production of milk, which is rich in mineral salts, especially lime and phosphorus. Not only has the tremendous increase in milk production caused a greater mineral requirement, but the feeds used today are often grown on soils depleted in the essential mineral elements, resulting in a deficiency in the crops grown on such soils." The station found that the need of both growing and milking cattle for mineral matter was met by allowing free access to a mixture of 2 of bone meal to 1 of salt.

An exclusive wheat ration was found by the Washington station to be deficient in sodium for normal growth and reproduction of rats. From the results it appears that 0.23 per cent of sodium is too small an amount, that 0.53 per cent is the most satisfactory when both growth and reproduction are considered, and that 0.79 per cent and amounts above this are detrimental.

Iodine is now generally recognized as essential in the nutrition of mammals, and much attention is being given, particularly in goitrous regions, to the supply of it in food or water or both. The Illinois, Iowa, Montana, Ohio, Washington, and Wisconsin stations, among others, have contributed to the knowledge of the subject.

Recent experiments by the Iowa station show that feeding of iodine in the form of potassium iodide to young growing swine in dry lot and on rape pasture resulted in increasing the average daily gain approximately 10 per cent and decreased the feed required for 100 pounds of gain 10 per cent. The pigs given potassium iodide made greater growth in height, length, and leg circumference. Inasmuch as swine may be handicapped because of a deficient supply of iodine, and yet show no gross or unusual signs of goiter or other iodine deficiency troubles, the Iowa station thinks it is good practice in goitrous regions to use iodine in the form of iodide in the feeding ration, putting it in the drinking water, or with the feed, aud using from one-third to an ounce of either sodium or potassium iodide to the hundred pounds of mineral mixture, which is kept before swine at all times.

Range cattle given an ounce per head daily of a mixture of a finely ground limestone, spent bone black, and potas-

sium iodide, with salt ad libitum, showed increased daily gains, decreased food required per 100 pounds of gain, and increased selling price.

Lambs of ewes given 2 to 8 grains of potassium iodide daily were impaired in vigor and resistance to disease. Iodine was eliminated in the milk of the ewes for 5 to 15 days after discontinuing the dosing.

HORSES

Injurious effect of wide rations on horses.—Feeding horses an extremely wide ration, mainly oat straw, even for a few months of each year was found by the South Dakota station to result in permanent injury to health and efficiency. There was a sacrifice of bone structure to maintenance of life. There was a decline in the ability of the horses to digest all nutrients except fat, the nutrient most relied on for energy upkeep. In case of the fats the digestive capacity was on the average more than doubled, notwithstanding a heavy decrease in the digestion coefficient of the ration as a whole.

CATTLE

Profitable cattle feeding in Arizona.—Cattle feeding in Arizona can, according to the Arizona station, be made profitable in conjunction with other farming operations, success depending upon the efficient use of the farm roughages—alfalfa hay, silage, pasture, and cottonseed hulls—supplemented with cottonseed meal and, under certain conditions, grain, and upon the development of an outlet for good fat cattle in the California market.

Profitable use of roughage in cattle feeding.—A profitable means of utilizing roughage when it is abundant on the farm is, according to the Indiana station, to winter steers on it, reserving the grain feed for summer use. Cattle of good quality can often be fed with advantage in this way. Corn silage was found to be a readily available and economical feed for fattening cattle.

Carrying capacity of pastures.—The North Dakota station found 10 acres of pasture per steer more than enough for maximum gain per head. One steer to 7 acres produced the maximum gain. Five acres per steer did not provide enough feed to produce a maximum gain during a period of five months and was overgrazed. With one steer to 3 acres the pasture was seriously overgrazed and the animals underfed. Deferred and rotation grazing with one steer per 4.4 acres provided enough feed to give a gain about 10 per cent below the maximum, with no serious injury from overgrazing.

Dry lot v. pasture for fattening steers.—Larger gains were made in experiments at the Illinois station by cattle fed in dry lot than on pasture, but the pasture gains were somewhat cheaper. Bluegrass proved slighty superior to sweet clover pasture. Considerably larger gains were obtained from a ration of shelled corn, cottonseed meal, and corn silage than from any other ration used.

Soft corn for beef cattle.—On the basis of the amount of beef obtained per acre, various methods of feeding soft corn tested by the Illinois station ranked as follows: (1) Ear corn silage, (2) shock corn, (3) gathered from field, and (4) corn pastured in the field. However, all methods gave results that would be considered satisfactory, proving that soft corn is a valuable feed for fattening cattle, the difference between its feeding value and that of sound corn being surprisingly small. Based upon the dry matter content, the soft corn was the more efficient feed. In appearance the quality of the beef of cattle fed sound corn, however, was superior to that of the beef produced on soft corn. The sound corn carcasses contained 2 per cent more fat and 2 per cent less lean than the soft corn. No difference in palatability was observed.

Calf meal gruel.—Calves were successfully raised at the New York Cornell station on a calf meal gruel, consisting essentially of 250 pounds of yellow corn meal, 250 pounds of red dog flour, 150 pounds of ground oat groats, 150 pounds of linseed oil meal, 100 pounds of ground malted barley, 100 pounds of soluble blood flour, 10 pounds of calcium carbonate, 10 pounds of precipitated bone meal, and 10 pounds of salt, and having a composition of water 9.3 per cent, ash 5.1, protein 24, crude fiber 3.5, nitrogen-free extract 53.7, and fat 4.4 per cent. The gruel was made by mixing the calf meal with water at about 100° F. in the proportion of 1 to 5 by weight. It was fed three times a day.

Acetic and propionic acids and ethyl alcohol was found by the New York Cornell station in the feces of calves fed on a cereal-gruel diet. This was taken to indicate "that young calves do not have the power to completely digest large amounts of carbohydrates consisting essentially of starches. Therefore the partially digested food residues are acted upon by bacteria, resulting in the production of acids and alcohols."

Concentrated rations for calves.—The Michigan station found that calves fed milk alone, milk and grain, or grain alone died with symptoms of tetany and frequently showed bone changes similar to rickets in other animals. The addition of various mineral supplements gave only temporary relief. Cod-liver oil showed little if any curative effect on the trouble. A high leucocyte count and low calcium content of the blood indicated that death on the concentrated ration was due to toxemia.

Feeding baby beeves.—Satisfactory baby beef was produced at the Kansas station on a ration of shelled corn, cottonseed meal, and sorghum silage. The calves gained 2.08 pounds per day, paid the market price for shelled corn and cottonseed meal, and left a return of over $5 per ton for sorghum silage, which was produced at the rate of 18 tons per acre. A higher degree of finish and a higher selling price per hundredweight were secured when alfalfa hay was added to the ration; and the longer this was fed as a part of the roughage the greater was the degree of finish.

Corn and cob meal proved to be a superior feed for fattening baby beeves and shelled corn to be excellent for finishing, in experiments at the Minnesota station. Ground barley was used satisfactorily in place of corn, although it did not produce quite so good gains toward the close of the period, and less pork was made by the hogs following the steers. The addition of oats to a ration which included corn did not prove profitable. As a rule, it did not pay to grind shelled corn or oats for baby beeves. The purchase and use of linseed meal were usually profitable. It was necessary to supplement silage with a protein concentrate. As a rule, it was most profitable to feed baby beeves until they were well finished before marketing them.

Effect of age and sex on gain in cattle.—In a comparison at the Nebraska station of 2-year-old steers, 2-year-old spayed heifers, yearling steers, yearling spayed heifers, yearling open heifers, steer calves, open heifer calves, and spayed heifer calves fed the same ration, the 2-year-olds made the most rapid gains, the steers gaining slightly more than the heifers. Of the yearlings the open heifers gained more than either the spayed heifers or the steers, whereas in the calf class the steers gained materially more than either of the heifer classes. Calves made the most efficient use of feed.

In experiments at the Arizona station the most efficient use of feed was made by yearling steers, the economy of gains diminishing with older cattle. A greater spread between buying and selling prices was required with older cattle. The records made by yearling heifers were excelled slightly in almost every respect by those of yearling steers, but the heifers had a more even distribution of fat and reached a market finish 10 days earlier than did the steers.

Silage for cattle.—The silo has proved, in experiments at the Arizona station, to be a better and less wasteful method of storing hegari for feed for cattle than stacking. Steers fed the silage made larger and more economical gains and attained a higher market value than did those fed dry forage. Heading, threshing, or grinding the grain for feed did not prove profitable in these experiments. Supplementing hegari silage with grain increased the dressed weight of the steers.

Mixed silage made of soy beans or cowpeas with corn or cane kept well, was more palatable to beef and dairy cattle, and produced more milk and butter than silage from corn alone, in experiments made by the Arkansas station. Corn made into silage was equal in feeding value, pound for pound of dry matter, to corn fodder ground to a meal.

SHEEP

Feeding range lambs.—Average range lambs were successfully fattened for the spring market by the Oregon station in 60 to 90 days on grain and alfalfa. Lambs to be marketed in March and April were fed alfalfa alone until 60 to 90 days before they were to be marketed and then given grain at the rate of 1 pound per head per day in addition to all the hay they would eat. Lambs on hay alone made but little gain, but the increase in market price during the winter months usually gave a fair return for the hay.

Soy beans for lambs.—The Illinois station found that soy-bean hay, although not fully equal to alfalfa hay, may be used to advantage in place of alfalfa in the rations of fattening lambs. Soy beans, whole or ground, were not so palatable as soy-bean oil meal or linseed-oil meal and gave somewhat slower gains. There was no advantage from grinding the soy beans. Soy-bean oil meal used as a supplement to shelled corn and soy-bean straw gave somewhat more rapid gains with slightly less feed per 100 pounds of gain than did linseed-oil meal. Soy beans and soy-bean oil meal were successfully used by the Indiana station as substitutes for cottonseed meal in rations for fattening lambs. The gains were as rapid

and as economical with soy beans as with cottonseed meal. Lambs fed soybean oil meal sold as high on the market as those fed cottonseed meal. Those fed soy beans sold for approximately 10 cents less per 100 pounds.

Sorghums v. corn for fattening lambs.—In tests at the Texas station grain sorghums showed practically the same feeding value as corn.

SWINE

Inbreeding.—The advantages of limited inbreeding were shown in an experiment by the Oklahoma station. The limited inbreds were produced by matings of half brothers and half sisters, the controls being from unrelated parents. The limited inbred litters averaged 7.2 pigs, the controls 7; and the average number weaned was 4.6 for the inbreds and 2.5 for the controls. The average birth weight of the inbreds was 2 pounds and of the controls 2.2 pounds. The average weight at weaning (60 days) was 32.2 pounds for the inbreds and 22.4 pounds for the controls, while the percentage of pigs alive at weaning time was 63.9 for the inbreds and 35.7 for the controls. The percentage of males in the inbred litters was 58.3 and in the controls 50.

Types of hogs.—Studies of the relation of feed to growth of lard type (Poland China) and bacon type (Yorkshire) pigs, by the Missouri station, showed no large or consistent differences in the physical or chemical character of the carcasses of the two types. The cost of gains in protein increased rapidly after the animals reached a weight of 200 pounds. On the other hand, gains in fat became constantly less expensive as the pigs grew from 100 to 300 pounds. A little over 40 per cent of the net energy consumed by the animals was stored in their tissues. The calculated daily maintenance requirement (including bodily activity) was approximately 2,850 calories per square meter of body surface and 50 calories per kilogram of live weight. The surface area of the animals was calculated by the following formula: $S=L^{.6} \times W^{.4} \times K$, in which S is the surface area in square centimeters, L is the length of body in centimeters, W is the weight in kilograms, and K is the constant 175. L is obtained by measuring with a tape from the point of withers to the root of the tail.

The Illinois station found that hogs of the intermediate type showed slightly higher dressing percentages than hogs of the rangy type, and the intermediate carcasses were in better condition. Hogs self-fed on alfalfa pasture produced the fattest soft carcasses. The rangy carcasses contained more skin and bone than the intermediate carcasses. The intermediate carcasses produced better hams and bacon than the rangy carcasses. Difference in cutting percentages was small. The intermediate type proved to be superior to the rangy type both in dry lot and on pasture.

In a comparison of small, medium, and large types of hogs at the Iowa station, the large type required the least feed to reach a market weight of 300 pounds and the small type the greatest. The medium type, however, made a greater daily gain and required 30 days less than the large type and 41 days less than the small type to reach a 250-pound market weight.

Feeds and rations for hogs.—Much of the station work with swine has been of the nature of relatively simple comparison of various combinations of feeds. The effort in most cases has apparently been to obtain well-balanced and efficient, as well as economical rations with the feeds most readily available, and in this respect the work has given valuable practical results, particularly in the way of determining the extent to which one feed may efficiently replace another in the ration, profitable supplements to commonly used rations, and the value of newly introduced feeds. At the same time light is being thrown on questions of vitamin requirements and need of mineral supplements. Some results of recent station work with hog feeds and rations are briefly as follows:

A ration of yellow corn and tankage was improved by the South Dakota station for the winter feeding of fall pigs by adding chopped alfalfa and oil meal or buttermilk. Ground barley was a satisfactory substitute for part of the corn in the ration.

Dried, semisolid, or creamery buttermilk was found by the Minnesota station to be somewhat more effective in pork production than tankage, but the commercial buttermilk feeds were somewhat less economical as sources of protein than either tankage or creamery buttermilk. The three forms were about equally efficient in experiments at the South Dakota station. Semisolid buttermilk and tankage proved superior to tankage alone in experiments at the West Virginia station.

Skim milk was the most satisfactory protein supplement for weanling pigs tried by the Minnesota station, but tankage with rape pasture gave nearly as good results. Tankage was decidedly inferior to skim milk in dry-lot

feeding, but with good pasture, such as rape, there was little difference between the two.

Fish meal and semisolid buttermilk proved superior to tankage and semisolid buttermilk for young pigs in experiments at the West Virginia station. The addition of 5 per cent of fish meal to a ration of corn and shorts was found by the Florida station to increase the average daily gain 0.24 pound and to save 155.7 pounds of grain for each 100 pounds of gain. A comparison of fish meal and meat meal fed with shelled corn showed the fish meal to produce 50 per cent larger daily gains. Meat meal and cottonseed meal, equal parts by weight, fed with shelled corn, gave a slightly better gain than the fish meal and cottonseed meal. Pigs receiving fish meal made more rapid and economical gains in experiments at the North Carolina station than those receiving soy-bean meal. The soy-bean meal was very palatable and when fed under the "free-choice" system the pigs consumed more than was necessary to balance their ration.

Ground rye was found by the Wyoming station to rank above shelled corn for producing rapid gains in pigs, and less grain was required with rye than with hull barley, bald barley, or shelled corn. Pigs fed corn or bald barley dressed a higher percentage of carcass to live weight than those fed rye or hull barley. The pigs receiving bald barley, rye, or shelled corn finished with the fat in good hard condition, while hull barley produced a flabby, oily fat. In experiments at the Minnesota station pigs fed rations containing a large proportion of rye did not make satisfactory gains and the feed requirements were abnormally high. The most satisfactory results were obtained by feeding a ration of 50 per cent ground rye and 50 per cent creamery buttermilk. Attempts to supply the necessary protein by feeding milk casein and to make the vitamin content of the ration satisfactory through the use of cod-liver oil were not successful.

Buckwheat middlings proved superior to wheat middlings as feed for pigs, in experiments at the West Virginia station. A yeast-fermented mixture of rye, oats, tankage, and mineral mixture produced somewhat more favorable gains in pigs, in experiments at the Michigan station, than did a similar unfermented mixture, but the advantage gained did not cover the cost of the yeast. Yeast-fermented buckwheat middlings and corn proved superior to unfermented wheat middlings and corn, in experiments at the West Virgiain station.

Peanuts and soft pork.—Experiments at the North Carolina station showed that every pound of oil in peanuts fed to pigs required 2.25 pounds of starch in the the hardening feed. Hardening feeds fed after the peanuts produced harder pork then when fed with them. Hogs weighing less than 150 pounds showed a greater tendency to softness than those weighing more.

The Georgia station found that pigs weighing about 100 pounds, fed peanuts for a gain in weight of about 40 pounds, could not be hardened by feeding corn without bringing them to a weight considerably beyond the limit of economy. Experiments with peanut oil added to standard rations showed that an animal weighing 125 pounds can consume 300 grams of the oil daily with no apparent physical disturbances.

Coconut meal for pigs.—Good results in feeding coconut meal to pigs were obtained by the Guam station. Pigs fed coconut meal with mineral mixture and pasture consumed 19.25 pounds of meal per pig per day for 80 days and made an average gain of 0.8 pound per day at a cost of 2 cents per pound, with no harmful effects. With free access to corn and coconut meal the pigs ate more of the latter than is generally recommended.

Alfalfa hay for wintering brood sows.—The use of alfalfa hay considerably reduced the feed cost of wintering brood sows, in experiments at the Delaware station. Sows consumed 2.35 pounds per head of the leaves daily, with a saving of 27 per cent in cost of concentrates over a lot fed corn and tankage.

POULTRY

Basal heat production of chicks.—The body surface of White Plymouth Rock chicks can, according to the Illinois station, be estimated by the formula $S=5.86 W^{.5}L^{.6}$, S being the surface area in square centimeters, W the live weight in grams, and L the rump-to-shoulder distance in centimeters. The average basal heat production of White Plymouth Rock cockerels per square meter of body surface per day was found to be 849 calories, and for capons 768 calories, these figures applying to birds from 2.5 months to 1 year of age. For younger birds the figures may be may be much greater.

Grain v. grain and mash for laying hens.—In a comparison by the South Dakota station of hens fed oridinary farm grains alone with those receiving the same ra-

tion plus 20 per cent tankage mash, the cost of feed being about the same, the mash-fed hens laid a third more eggs than those receiving grain alone. The hens receiving grain alone became excessively fat and stopped laying before those fed mash.

Meat in rations for egg production.—A mash containing 20 per cent meat scrap was found by the Kentucky station to yield more eggs and more profit than one containing 5, 10, or 15 per cent. The maximum egg yields and greatest returns were obtained when a mash containing 10 per cent of meat scrap was fed in addition to skim milk to supplement the grain ration. Hens receiving cottonseed meal during an 11-month period at the Texas station produced 123 eggs per hen, whereas those receiving meat scrap produced 147 eggs per hen. The feed consumed by the hens receiving cottonseed meal amounted to 5.8 pounds per dozen eggs, and by those receiving meat scrap 5.5 pounds. Fish meal was equal to meat meal for egg production in experiments reported by the North Carolina station.

Soy beans for laying hens.—In view of the fact that cereal grains are unsatisfactory as the sole constituents of rations for laying pullets and that animal protein concentrates, while greatly improving the rations, are expensive, the Indiana station has attempted to find efficient protein supplements from other sources. It found that soy beans or their by-product soy-bean oil meal gave practically the same results as the animal proteins when the ration was properly supplemented with minerals.

Soy beans were found by the Missouri station to be a satisfactory substitute for meat scrap in rations for laying hens if properly supplemented with mineral mixture (1 part of salt to 4 of bone meal). In the experiments from which the conclusion was drawn, a basal mash, consisting of equal parts of bran, shorts, and corn meal, to which was adddd 30 per cent of soy bean meal and 5 per cent of mineral mixture, was used. This mash was fed ad libitum.

Cottonseed meal for egg production.—In a comparative test, by the Arizona station, of protein supplements, cottonseed meal rations produced 75 eggs, meat scrap rations 105 eggs, and dried-buttermilk rations 111 eggs per bird in the same period of time. The New Mexico station found that a ration containing cottonseed meal produced a dozen eggs more cheaply than one containing tankage as a source of protein, but as the tankage-fed hens produced more eggs, there was a slightly larger profit over feed cost. During the months when eggs brought less than 35 cents per dozen the cottonseed meal hens made the larger net profit, while during the months when eggs were higher priced the tankage-fed lot gave the larger profit. The price of eggs would therefore seem to be the determining factor as to whether or not cottonseed meal can be fed to advantage.

Milk products for growing chicks.—The Minnesota station found that with milk by-products available at low or no cost, an economical ration for young and growing chicks is the hull-less grains and all of such milk products as the chicks can be induced to consume. Both dried buttermilk and condensed buttermilk were found by the Kentucky station to be efficient commercial sources of protein and desirable for use when skim milk or buttermilk is not available on the farm. Experiments at the New Mexico station showed that milk is an economical source of protein when fed alone with scratch, but tankage is more economical than milk when the by-products of grains and grains themselves are used for a portion or as the entire mash mixture. Adding milk to a ration already high in animal protein was not economical. Experiments reported by the North Carolina station indicate that dried milk, condensed milk, meat meal, and fish meal were of about equal value as sources of protein for young chicks.

Animal protein for growing chicks.—The Nebraska station found that growing chicks during the first nine weeks of their growth period tolerated and even made good use of animal protein concentrates to the extent of 19.5 per cent of the total ration, when added to a mixed ration of corn, wheat, and barley plus minerals. The growth rate was progressively improved as the amount of protein was increased to 10.4 per cent of the total ration.

Vitamin and light requirements of fowls.—Chicks were successfully raised by the Missouri station on synthetic diets, with comparatively low mortality. Leg weakness, which occurred in some cases, was cured by adding rich sources of vitamin B, but exposure to direct sunlight was of no apparent benefit. Meat protein substituted for part of the casein did not improve the diet. When foods such as dried egg yolk, polished rice, and dried liver were added, growth was markedly accelerated and practically the optimum rate was attained. Using extracts of liver was of no benefit. Chicks receiving diets containing extracted polished rice grew at a subnormal rate, but those receiving

a diet containing 1 per cent of the extracted material grew at approximately a normal rate and appeared normal in all respects. The growth-promoting factor carried by the polished rice was apparently removed by extracting with dilute acetic acid.

Chicks exposed to sunlight were at all times in better condition than those kept in the laboratory, in experiments at the Illinois station, indicating that results of laboratory experiments with vitamin-deficient rations can not always be safely applied to farm conditions. In these experiments the vitamin A deficiency seemed to be much more serious in retarding growth and increasing mortality than vitamin D deficiency.

"Nutritional roup," according to the Kansas station, is caused by a lack of vitamin A ond not a lack of vitamin D. Exposure to ultraviolet light was shown to enable the hen to put vitamin D into the eggs.

The importance of light in the normal growth and development of chickens received added confirmation in experiments reported by the Maine station. The failure in growth of chicks receiving insufficient ultraviolet light was traced to imperfect development of bone tissues. Although an abundance of bone-forming material was present in the food and blood, it was not deposited in the bones in sufficient amount. Exposure to ultraviolet light increased the hatching quality of eggs but did not increase the number of eggs laid or the fertility of the eggs to any appreciable extent.

Exposure to direct sunlight proved to be a very effective means of preventing leg weakness in chicks at the Ohio station. One-half hour of direct sunlight was more effective in curing the trouble than the feeding of green clover.

Relation of body weight to egg production.—In a study of the relation of body weight to egg production and of the most effective means of maintaining the best weight for this purpose, the New Jersey stations found that regardless of age the bird must be in good flesh in winter if satisfactory egg production is to be realized. One of the best ways to bring this about was found to be to feed heavily on scratch grain throughout the summer. From 4 to 4.5 pounds appeared to be the best body weight for the group of Leghorns studied.

The West Virginia station found no apparent direct correlation between body weight and egg weight in White Leghorns. The average size of egg apparently had no relation to the number laid. The ration, however, had an influence on the size of the egg.

Variations in eggs.—Marked variation in size, color, and shape was found by the North Dakota station in the first eggs laid by pullets of the same variety. Weight variations ranged from 16 to 26 ounces per dozen. Some pullets laying small eggs at first soon produced normal-sized eggs, while others never did so. The shape and color of the egg of any individual varied but slightly. There appeared to be a relation between the eggs produced by a hen and those of her progeny, especially as to color and probably as to size and shape.

Growth of progeny of heavily fed and poorly fed hens.—In experiments at the West Virginia station there was no significant difference in the rate of growth of chicks hatched in the spring from eggs laid by birds fed for heavy production during the preceding winter as contrasted with the growth of the progeny of fowls poorly fed for egg production.

Incubation in dry climates.—It is particularly difficult to maintain proper moisture conditions in the incubation of eggs in a dry region like that of New Mexico. The New Mexico station found the use of trays of wet sand in the bottom of the incubator to be an economical and effective means of improving the moisture conditions and increasing the hatch, proving better than using a water pan or sprinkling the eggs. A temperature of 101° F. for the first week, 102° for the second week, and 103° for the third week gave the best hatches. Cooling the eggs during incubation appeared to be advantageous. The head radiation type of incubator proved to be best under the conditions, with no marked choice between hot water and hot air types.

Growth of the chick embryo.—The embryo of fowls showed a marked acceleration in growth at about the twelfth day of incubation in experiments at the Illinois station, reaching a maximum on the sixteenth day. A marked retardation of growth occurred on the seventeenth day. During the course of incubation the weight of the egg decreased 11 grams, the weight of dry substance about 3.5 grams, and the energy value about 28 calories. There was a distinct transfer of calcium from the shell to the embryo.

DAIRYING

Breeding.—The dam's record is, as a rule, a poor guide as to her ability to produce high butterfat-producing

daughters, according to studies with Guernseys reported by the Missouri station. On the other hand, the daughter progeny performance of a sire is a reliable index of the son's transmitting ability to his daughters; therefore, bulls from proved sires of large-producing daughters should be given major consideration in breeding for high production. From a study of the progeny performance of Guernsey sires, based on the average mature equivalent fat production of the daughters and their dams, the station found that "the average production of a sire's daughter was a better index of his transmitting ability to his sons and through them to his granddaughters than is the dam's own record of production an index of her transmitting ability to her sons and through them to her granddaughters. In other words, a proved sire of high producing daughters, or a son of a proved sire is, on the average, greatly superior to a son of a high-record cow in transmitting high production to his daughters."

In a study of inheritance of milk production by means of pedigrees the Maine station found little or no influence of inbreeding, relationship, or famous ancestors on the production of dairy sires. Intensive inbreeding experiments, especially with small animals, mating brother and sister for a number of generations, has generally resulted in concentration of the prepotency of the animal but also in decline in vigor and probably fertility. It appears from this study that the parents and grandparents, sisters and half sisters, and to some extent cousins are the important relatives on which to base an estimate of the productive worth of the animal and that the animals on which greatest dependence may be placed in reading a pedigree are the recorded performances of the dam, full sisters, and half sisters, and next to these stand the recorded performances of the grandparents.

Type appears to have some relation to milk production but little or no relation to butterfat percentage, according to the Maine station. Pedigree is of doubtful value, except when accompanied by records on a large number of animals found within the pedigree. The choice of dairy cattle by their performance is shown to be a much more important means of selecting and breeding to increase productivity of the herd.

Breeding studies of the Texas station emphasize the value of the progeny test. It is held that much of the propaganda in favor of purebred sires is too sanguine. Not all registered bulls prove to be good sires, and bulls with famous ancestors two or three generations back may be incapable of improving a herd. It is therefore considered a serious mistake to encourage a farmer to think that by merely using purebred sires and culling his cows he can invariably produce a herd with a high average of production.

Progress in developing a dual-purpose cow especially suited to the conditions in Alaska is reported by the Alaska stations. Several promising Holstein-Galloway and Galloway-Holstein crosses have been obtained, which appear to be intermediate between the parents in milk yield and fat content of the milk, and are hardier than the Holstein.

Vitamin and light requirements for calves.—The Minnesota station reports that calves fed from birth on rations deficient in vitamin A but adequate in other respects showed characteristic symptoms in two months and survived only to the age of three or four months. Calves fed rations deficient in vitamin C made a normal growth to the age of 1 year and appeared to be normal on a ration so low in this vitamin that guinea pigs on the same ration died of scurvy within 20 days. No symptoms of scurvy appeared in the calves. Guinea pigs fed liver from calves raised to 1 year on a ration devoid of vitamin C were not protected from scurvy, indicating that the vitamin is not synthesized in the body of the calf. Of two lots of calves fed for 21 months on the same ration, one being kept in complete darkness and the other exposed to the direct rays of the sun daily, the calves in darkness showed no ill effects and, possibly, were in slightly better condition than those exposed to sunlight.

Mineral requirements.—A low mineral ration had no prolonged ill effects on the general condition of aged cows, in experiments at the Massachusetts station, the change in body weight being insignificant and the composition of the milk unaffected. Mineral supplements added to a low mineral ration had no pronounced effect. However, the reproductive functions were seriously disturbed by the low mineral ration, and recovery was very slow.

The alkaline reserve in the blood was found by the Michigan station to be lower in case of cows receiving considerable grain in addition to roughage than in those receiving exclusively roughage. Unfavorable pasture conditions lowered but heavy milk production had no effect on the alkaline reserve, which is contrary to the generally accepted idea that lactation drains the

body of minerals necessary to keep up the alkalinity of the blood.

The importance of adding mineral supplements to the ration of growing heifers may be overemphasized, according to tests made by the Michigan station, which indicated that ordinary rations containing adequate energy and protein also contain ample minerals, especially lime, for proper growth and development. Certain mineral mixtures proved to be detrimental. Raw rock phosphate was found to have an injurious effect on the health of dairy animals and affected the appetite for food and water, and hence is not recommended as a supplement to feed for dairy cattle.

Hay and green feed.—The mineral requirements of dairy cows were not met by a ration containing timothy hay as the roughage, in experiments reported by the Ohio station. Alfalfa, clover, soy beans, and sweet clover gave better results. They apparently supplied not only lime but also the unknown factor which aids the animal in utilizing the lime. Green grasses or legume hays, carefully cured, supplied more of this factor than hays that had been unduly exposed to the bleaching effects of the sun. Cows on pasture stored larger reserves of lime than those fed in dry lot.

The beneficial effect of properly cured hay and green food on dairy cows was shown in experiments at the Michigan station. Cows fed rations containing adequate amounts of energy, protein, vitamins, and mineral matter but no hay or green food failed to shed their winter coats of hair properly and otherwise did not thrive. They also failed to reproduce properly. The addition of good hay or green feed corrected these difficulties. The hay was most effective when cured with exposure to as little sunlight as possible. The general conclusion was that "a good ration, one containing plenty of well-cured hay or one supplemented with abundant pasture, is the basis of proper nutrition of dairy cattle."

Silage as feed for dairy cows.—There are reported to be 500,000 silos in the United States, being especially numerous in those regions where dairying is most highly developed. More than 100,000 are reported from Wisconsin alone. The Wisconsin station has therefore given paticular attention to the study of the process of silage making. The first significant change observed was the rapid disappearance of oxygen and increase of carbon dioxide, followed by rise of temperature and increase of acid. Various microorganisms were found to take part in the process, but the conditions were especially favorable for the growth of the lactic acid group. "The bacteria produce profound chemical changes in the plant tissue. Many of the carbohydrates are converted into carbon dioxide, ethyl alcohol, and organic acids; the proteins are partly hydrolyzed into proteoses, peptones, amino acids, and ammonia." Of the aciduric bacteria present, the pentose fermenters were especially active. Aside from the breaking down of pentoses, the most of these organisms play an important rôle in formation of alcohol. Approximately 10 per cent of the dry matter, 25 per cent of the pentosans, and 25 per cent of the starch contained in the corn forage were destroyed as a result of ensiling for four months. Though inoculation with certain bacteria produced a more vigorous and sustained fermentation, it is not considered of practical importance under ordinary conditions. With corn of uneven ripeness it may be of advantage.

Cows fed corn silage maintained body weight better and produced approximately 10 per cent more milk and 6 per cent more butterfat, in experiments at the Indiana station, than those not fed silage but receiving about a third more digestible protein. The station concludes that the feeding of silage is neceessary for economical dairy production.

Sorghum silage proved to be from 93 to 95 per cent as effective as corn silage for milk production, in experiments at the South Carolina station, and the sorghum yielded 14 tons of silage per acre as compared with 8 tons from corn. Cows fed corn silage produced more milk than those fed Napier grass silage, in experiments at the Florida station. In a comparison of sunflower silage with oat and pea silage, the Montana station found that when fed with alfalfa hay and a small grain ration there was practically no difference in the feeding value of the two silages, the daily yield of butterfat being practically the same; but the sunflowers yielded about twice as much per acre as the oats and peas.

Soy beans for milk production.—The steady extension of the culture of the soy bean and the various uses which may be made of its products have given rise to many investigations by the experiment stations, especially with regard to its feed value.

Ground soy beans are considered by the Indiana station one of the best protein supplements that can be used in the dairy ration, giving better results than soy-bean oil meal or linseed-oil

meal. The South Dakota station found ground soy beans to be more digestible and more efficient than old-process linseed meal for milk and butterfat production. The beans were readily eaten even when they were the sole concentrate. They did not appreciably affect the quality of the butter produced, but apparently temporarily increased the percentage of butter in the milk of certain cows. More milk protein was produced from a pound of total crude protein from peanut meal than from either cottonseed-meal or soy-bean-meal protein, in experiments at the Virginia station. The relative gross efficiencies in producing milk protein from total crude protein were peanut meal 29.6 per cent, cottonseed meal 27.8 per cent, and soy-bean meal 27.9 per cent. On the digestible crude protein basis the efficiencies were peanut meal 50 per cent, cottonseed meal 46 per cent, and soy-bean meal 45 per cent.

Soy-bean hay was more efficient for milk and butterfat production than alfalfa hay in experiments at the South Dakota station. The hay, however, was not so economical a feed as alfalfa hay because of the lower yield. In experiments at the Minnesota station soy-bean hay and timothy hay were about equally effective in milk and butterfat production. Cows receiving soy-bean hay required only two-thirds as much grain as did cows receiving timothy for the production of an equal quantity of milk. The soy-bean hay was very palatable, less than 3 per cent being refused.

Cottonseed meal for dairy cows.—It was found by the North Carolina station that the injurious effects on health, milk production, and reproduction of heavy feeding of cottonseed meal to cows on limited pasture could be corrected by adding to the ration such things as casein, cod-liver oil, butterfat, alfalfa meal, and calcium carbonate, or bone meal, which increased the content of vitamins A and B and mineral matter. When these were added the cows ate more cottonseed meal without injurious effect, produced more milk, and gave birth to normal calves.

Sweet sorghum seed as a dairy feed.—The percentage of butterfat in the milk and the total butterfat production were increased by substituting ground sweet sorghum seed for corn chop in feed for milch cows receiving a liberal ration of alfalfa hay, grain, and silage, in experiments reported by the Kansas station. There was no particular advantage as regarded maintenance of body weight and milk production.

Apple pomace as a dairy feed.—A comparison of dried apple pomace, dried beet pulp, and corn silage for dairy cows, by the Virginia station, indicated the feeding value of the pomace to be 75 per cent of that of the dried beet pulp. It was found to contain three times as much total digestible nutrients and two and one-half times as much digestible protein as corn silage, while dried beet pulp contained four and four-tenths times as much total digestible nutrients and four times as much digestible protein as the silage.

Carrying capacity of land for cows.—A rotation of corn, corn, oats, and sweet clover, with the addition of a nitrogenous concentrate during winter proved adequate, in experiments at the Illinois station, to maintain 1 cow for each 4 acres of land in crops. The winter ration consisted of corn stover silage supplemented with 1 pound per head per day of a protein concentrate. During the summer the cows were carried on sweet clover pasture.

Self-feeders for dairy cows.—Permitting dairy cows to have access to a number of different feeds in self-feeders was found, by the Illinois station, to be uneconomical, although after a time the cows tended to accustom consumption to requirements. Very great differences were found in the feed preferences of the cows. The method proved to be safe from the standpoint of the health of the cow.

Relation of size of cow to milk production.—In a study of the relation of the size of cow to milk production, the Maine station showed that in case of 385 Holstein-Friesian cows varying in age from 1.5 to 10.5 years, averaging 3.9 years, with an average 7-day milk yield of 338 pounds, the average measurements were shoulder height 52.8 inches, hip height 53.8 inches, body length 62 inches, rump length 20.4 inches, body width 21.3 inches, thurl width 19 inches, body girth 73.2 inches, and weight 1,088 pounds. The coefficients of variation ranged from 3.7 to 15.1, the most variable measurement being weight, the least variable height at hips. All of these body measurements were found to be related to milk yield, an increase in any one of them being associated with an increase of yield. The most important element predicting milk yield was weight, followed closely by body length, body width, or girth.

Feed cost of milk production.—From a study of the feed cost of milk production the Illinois station concludes that "the nutrients required for lactation per pound of milk, N_L, may be expressed as a function of the fat percentage of

the milk, t, as: $N_L=K_L$ (2.66+t). The nutrients required for maintenance per pound of milk, N_M (because of the nature of the relation existing between fat percentage and size of cow and between fat percentage and milk yield), may also be expressed as a function of fat percentage, as: $N_M=K_M$ (2.66+t). Consequently the total nutrients required for milk production per pound of milk, N_T, may be expressed as: $N_T=K_T$ (2.66+t). The cost in dollars per pound of nutrients is practically unaffected by fat percentage and consequently the feed cost ($) per pound of milk, FC, may be expressed as: $FC=K$ (2.66+t). In these relations K_L, K_M, K_T, and K are constants so far as affected by fat percentage. The price differential for fat test as judged by the whole-milk markets of 101 cities seems to be tending to distribute about a mean which is approximately the same as the cost of production differential. The price of milk may be adjusted in proportion to the cost of production by the equation $P=\frac{P_b}{2.66+b}$ (2.66+t), in which P_b is the base price, b is the fat percentage to which the base price applies, and P is the price to be paid according to the fat test, t, of the milk delivered. This assumes that the cost of production is proportional to the feed cost of milk production, so far as affected by fat percentage."

Calculation of composition of milk.—The milk solids-not-fat and the total milk solids as determined in samples of mixed milk by chemical analysis were compared by the Illinois station with calculations made by the formulas—

$$\text{Total solids} = \frac{\text{Quevenne lactometer reading}}{4} + 1.2 \text{ fat},$$

$$\text{solids-not-fat} = \frac{\text{Quevenne lactometer reading}}{4} + 0.2 \text{ fat}.$$

This comparison showed that the calculated percentages of total solids and solids-not-fat were an average of 0.105 less than actual. Statistical analysis of the results indicated that when the suggested correction was made in this formula, the resulting percentages were sufficiently accurate for practical use in dairies where the determinations were made on samples of milk from a number of cows. A further comparison was also made between the calculated percentages of solids-not-fat and the actual percentage of solids-not-fat from 1,158 samples of individual cows. A larger correction factor was needed to make this formula conform with the average for the individual samples, but owing to the greater variability among individuals, its use was not recommended where determinations are to be made on milk samples of individual cows.

Micrococci in milking machines.—Numerous species of micrococci were found by the New York State station to be associated with milking machines. The species most commonly found in the tubes and teat cups were, in the order of their probable abundance, as follows: *Micrococcus candidus*, *M. freudenreichii*, *M. casei*, *M. conglomeratus*, *M. epidermidis*, *M. varians*, *M. flavus*, *M. aurantiacus*, *M. luteus*, *M. albus* and *M. aureus*. It was observed that where the parts which come in contact with the milk are submerged in sterilizing solutions to prevent bacterial growth between milking periods, micrococci are found more commonly than other bacteria. The predominance of micrococci under these conditions may be explained by the fact that they survive the sterilizing procedures used better than the other bacteria present.

Determination of fat in dairy products.—Various new methods of determining fat in dairy products have recently been extensively exploited, with the result that a number of stations have thought it necessary to study their relative merits. Comparative tests by the Connecticut Storrs station of the Röse-Gottlieb, Babcock, and Gerber methods on milk and cream led to the conclusion that there is no advantage in introducing another method to replace the Babcock method for this purpose. Comparative tests of the Röse-Gottlieb, Troy-Fucoma, and modified Babcock method for the determination of fat in ice cream led to the conclusion that "both the Troy-Fucoma and the modified Babcock method seem well adapted for ordinary factory use where simplicity and rapidity of the test are important considerations; however, results obtained in this study would seem to make it questionable if their use is justified in instances where careful analytical results are desired. * * * In view of the fact that the Babcock method for milk and cream is generally used in the United States and is recognized as official it seems advisable to develope if possible a method using Babcock equipment rather than to introduce a new method requiring the installation of new equipment."

Composition of butter.—Analyses of 2,051 lots of exhibit butter, examined by the Minnesota station, showed an average of 83.46 per cent fat as compared with

82.21 per cent for 363 market samples taken in 1923 and 81.31 per cent for 1,000 market samples manufactured during the first four months of 1925. The average salt content of 2,051 exhibition samples was 1.76 per cent; for 363 market samples in 1923, 2.23 per cent; for 1,000 samples of market butter in 1925, 2.31 per cent. The 230 samples scoring below 90.5 contained 1.98 per cent of salt as compared with 1.29 per cent in 366 samples scoring above 93.5. The results of analyses of butter from various sources showed the need and the advantage of more attention to standardizing and controlling the composition.

Butter making.—In experiments reported by the Illinois station no one neutralizer showed an advantage over another as far as the quality of the fresh butter was concerned, except that a slight bicarbonate flavor was noted where sodium bicarbonate was used. After storage for 60 days the butter made with soda ash or bicarbonate did not hold its quality as well as did that in which lime was used. With a combination of neutralizers, the best results were obtained when lime was used first, followed by soda ash or bicarbonates. The miixng of the two neutralizers before use resulted in a lower quality of butter. The butterfat losses in the buttermilk was greater when either soda ash or bicarbonate was used than when lime was used. Fat losses in buttermilk can be reduced by the addition of common salt and hydrochloric acid to the cream at time of churning.

Butter made from unripened sweet cream was found by the Utah station to score as high as that made from ripened cream and to keep much longer in cold storage without deteriorating. Adding starter to the sweet cream immediately before churning improved the flavor of the butter slightly and did not impair its keeping quality.

Cooling cream on the farm is both practicable and highly desirable, according to the Indiana station, which has devised simple and effective means of bringing this about. The station has shown that butter scoring 90 points or better can be made from cream cooled and delivered at intervals of four days or less, and that such butter will stimulate the consumptive demand and net better returns to both cream producer and the creamery man.

Whipping properties of milk and cream.—The New York State station found increased viscosity and decreased surface tension to be associated with good whipping quality. The viscosity increased with aging and with increased percentages of fat. Pasteurization slightly reduced the viscosity of milk and greatly reduced the viscosity of cream. The effect of aging on viscosity was inhibited to a large extent by pasteurization. The surface tension of milk and cream decreased with an increased fat content, and it usually decreased with aging. Pasteurization usually increased the surface tension and aging would not reduce it to normal. The whipping qualities of cream were improved by increased percentages of fat and aging. Pasteurization had a slightly detrimental effect.

Roquefort cheese.—The California station reports successful manufacture of Roquefort cheese from goat's milk, cow's milk, or a mixture of the two, the goat's milk cheese being equal in quality to the imported. The average yield of Roquefort cheese from goat's milk testing 3.4 per cent butterfat was 10.34 pounds for each 100 pounds of milk. The factory procedure found most satisfactory is described.

Ice cream.—The fact that 250 to 300 million gallons of ice cream, or approximately 2.5 gallons per capita, are consumed annually in this country indicates the extent of such use of milk and its products. According to the Indiana station, this great consumption has indirectly been the cause of a great difficulty in ice cream making, namely sandiness, due to the necessity of making increased use of concentrated milk products. This defect is characterized by the presence of numerous hard, sharp, crystalline granules, which give the cream a gritty feel. Cream containing 7 per cent or more of milk sugar corresponding to 13 per cent or more of milk solids was generally found to be sandy. Twelve per cent of solids-not-fat is considered a safer limit and high enough for practical purposes.

In a study of the effect of different proportions of milk solids, fat, and sugar on the physical properties and quality of ice cream the Missouri station found that an increase in the milk solids increased the viscosity-titrable acidity, lowered the freezing point, increased the time required to freeze the mixture, and lengthened the rate of melting of the frozen mixture. Each additional increment of 2 per cent of butterfat to the mixture decreased the specific gravity and increased the viscosity. The overrun increased with an increase of fat up to 10 per cent but decreased above this, while the viscosity continued to increase. No direct relation was found between the fat content and the hardness of the ice

cream. An increase in the fat retarded the melting point. Each additional increment of sugar up to 12 per cent lowered the freezing point of the mixture, delayed freezing, increased the overrun, and improved the flavor, body, and texture. Thereafter the overrun was correspondingly depressed and the flavor, body, and texture became inferior.

Variations in texture of ice cream appear, according to studies reported by the New York State station, to be due not so much to the size of the incorporated air cells as to formation and growth in size of ice crystals and spines. The size of the air cells was not altered by variations in the composition of the cream, but homogenization reduced their average diameter about 50 per cent and the cells also became smaller as the freezing process continued. Sugar improved the texture by reducing the amount of ice formed. The protective colloid action of gelatin in inhibiting ice crystal growth was no greater than the action of casein. Milk fat prevented the formation of large ice crystals by mechanically obstructing their growth. Milk fat and solids-not-fat had a greater combined effect on texture than either alone. Homogenization increased the combined action of milk fat and solids-not-fat in making ice cream smooth as shown by a further reduction in the percentage of gelatin required to form a gel.

The organisms that cause "pin point" colonies in ice cream were shown by the Kansas station to be sufficiently resistant to heat to survive pasteurization and, apparently, some actually grow at pasteurization temperatures, resulting in some cases in the ice cream actually having a higher bacterial count after pasteurization than before. No satisfactory method of controlling these organisms was found.

DISEASES OF ANIMALS

Equine anemia.—A disease of horses apparently identical with that known variously as infectious equine anemia, swamp fever, infectious anemia, etc., is reported by the Nevada station. "The disease is characterized clinically by irregularly remittent fever, rapid emaciation, marked loss of energy, depletion of red blood cells in most cases, edema, usually bloody nasal discharge, and eventually death. The mortality is nearly 100 per cent, real recovery rarely, if ever, taking place. The disease is transmissible to other horses by the injection of infected blood or splenic emulsion, the period of incubation being from about two weeks to several months. The etiological factor is apparently ultramicroscopic, since the disease can be reproduced by the injection of Berkefeld filtrates, and is not recognizable by ordinary staining methods in smears from the blood, tissues, or exudates and transudates. The natural mode of transmission is not known, but is most likely through the bites of insects. Methods of treatment thus far used have proved unsuccessful, killing the infected animals being necessary to prevent spread of the disease. A positive diagnosis can only be secured by animal inoculation. Animals other than equines are not susceptible to the disease."

Infectious abortion.—Infectious abortion continues to be a leading subject of investigation by many of the stations. The Connecticut Storrs station shows, from 11 years' records of the college herd having 16 reactors to 14 nonreactors, that the nonreactors earned annually about $28 more per cow than the reactors. The loss in milk production for the 11 years chargeable to the presence of abortion in the herd was therefore $4,984. To this may be added a loss of $2,076 due to depreciation of the reactors and $928 due to loss of calves, or a total of $7,988 resulting from the presence of the 16 reactors, which amounts to about $45 per year for each infected cow.

From studies of methods of making agglutination and complement fixation tests and of their diagnostic value, the Connecticut Storrs station concludes that "by paying particular attention to the production of a potent bacterial antigen which is at best but slightly anticomplementary, and by following the rules governing both the agglutination and the complement fixation tests, these methods may be applied satisfactorily in the diagnosis of infectious abortion. Their constancy and reliability make them indispensable in the study and control of this disease." The two methods are considered by the station of equal importance, though the agglutination test is by far the simpler and more economical. The use of both is recommended, one serving as a check on the other. Attention is called to the possibility of obtaining negative results by the two serological methods at or near the time of calving of infected animals, and further tests on such animals after an appreciable interval following the calving are recommended. The Washington station found the agglutination test for abortion to be of considerable value as a herd index of

the presence or absence of abortion infection, and where it was used repeatedly in an infected herd it was of value in determining infection in individual cows; but its value was limited when applied to individual cows in an infected herd the first time. Not infrequently recently-infected pregnant cows failed to show a reaction, subsequently aborted, and then, as a rule, developed the reaction.

In view of the great demand for help in eradicating infectious abortion from dairy herds, the Connecticut Storrs station has undertaken to test a limited number of blood samples for *Bacterium abortum* infection, charging a fee of 75 cents per sample " for the first general herd test and for each regular semi-annual or annual test following successful eradication, 35 cents each for the first immediate follow-up test during the period of elimination, and 25 cents per sample for each of the remaining follow-up tests. The lower charges for the follow-up tests are made possible by employing the agglutination method alone instead of the more elaborate procedure which involves both the agglutination and the fixation methods."

In a study of the location and longevity in calves of *B. abortum* ingested with milk, the California station found the organism to be quite generally distributed through the lymph glands of the head and digestive tract, and also in other parts of the body, while infection was present in the milk. The longest period in which they were recovered following the removal of infection was from the atlantal gland of one calf 7 weeks after infection was withdrawn, and in the posterior pharyngeal gland of another calf 11 weeks afterward. Blood tests of these calves showed that the ingestion of virulent organisms in quantity did not develop agglutinins in the blood, indicating that in the control of the disease by the agglutination test no dependence can be placed on the results of the test applied to the blood of calves. It was found that the organism passed through the entire digestive tract and was eliminated with the feces of suckling calves fed either artificially or naturally infected milk.

B. abortum probably does not persist in the tissue of newborn calves from prenatal infection or through ingestion of milk containing the organism, according to experiments reported by the Michigan station. No evidence was found that calves from infected cows are more susceptible to calves' diseases or that the breeding efficiency is impaired in any way.

Attempts to control infectious abortion by temporary isolation of aborting cows, destruction of fetuses and their membranes, and disinfection of stalls in which abortions have occurred, or through separating the reacting animals from the negative animals but keeping them in the same barn were unsuccessful at the Oregon station. The adoption of a system similar to the Bang system in tuberculosis control has given satisfactory results. The yearly average milk production per cow in the infected group was 35 per cent less than in the abortion-free group.

Abortion in cattle was controlled by the Washington station in a Holstein herd 60 per cent infected by "dividing the herd into two groups, based upon the agglutination reaction and keeping the two groups separated when they are at liberty. This necessitates having separate pastures in the summer and two open sheds in the winter. All of the cows are milked in the same barn by the same attendents. The negative cows are brought in first and stanchioned, after which the positive group is brought in. In liberating the cows from the stanchions after milking, the positive group is turned loose first. This simple precaution of taking the cows in and out of the milking barn prevents any possible chance of a negative cow licking the body of an infected cow. The cows are brought into the barn for the purpose of milking only, and while there are fed their grain. No hay is handled, stored or fed in the milking barn. The milking barn has two rows of steel stanchions facing outward, one along each side of the barn. The entire floor is concrete and there is the usual gutter the proper distance behind the cows, with a broad alleyway between." After milking the manure is removed and the floors washed and scrubbed. Variable and inconclusive results were obtained with bacterins and viruses.

About 47 per cent of positively reacting cows at the Minnesota station eliminated the abortion organism by way of the placenta or milk, or both, and 37 per cent of the vaccinated animals and 27 per cent of the unvaccinated animals acted as spreaders of infection by eliminating the organism. The organism was eliminated from three individuals which failed to react positively to the agglutination test. In one of these the organism was recovered from the placenta and milk, in the second from the placenta alone, and in the third from the milk alone. Infection of the male was attempted by

repeated injection of large amounts of living organisms into the urethra and sheath but with negative results. Bulls were infected by way of the digestive tract, but only after repeated drenchings, showing a marked resistance to infection in this way. Autopsy showed no involvement of the genitalia. Bulls giving a positive reaction to the serologic test often failed to harbor the organism in the genital organs. Heifers given the living organisms directly into the urethra and vagina gave only transient reactions.

Three cases of a recurrent fever in young men which appeared to incriminate *B. abortum* as the causative agent were studied by the Michigan station. In two of the cases an organism was isolated from the blood which resembled *B. abortum* culturally and serologically. The blood of one reacted in a dilution of 1 to 200, of another in a dilution of 1 to 1,000, and of a third in a dilution of 1 to 400, using *B. abortum* as antigen.

Infectious white scours and pneumonia in calves.—The Minnesota station found that calves that received colostrum were less apt to contract these ailments. The colostrum appears to contain protective agents, which are developed in the udder up to the time of parturition. Careful feeding was found to be an important measure in the prevention and treatment of the infections. The use of barley water or gruel prepared by adding hot water to ground barley proved a good milk substitute for sick calves. Colon bacilli of various types were found to be the causative factor in most outbreaks. Control measures suggested are segregation and isolation.

Normal immunity of cows and calves to Bacterium coli.—The blood serum of the cow was found by the Missouri station to possess a marked bacteriolytic action toward *B. coli*, but in the unsuckled calf the bacteriolytic action was weak and there was a deficiency in complement. Both increased after nursing and when calves were fed ordinary milk in place of colostrum. There appeared to be an increase in complement and probably in bacteriolytic action with age. Agglutinins were not present in the blood of the newborn calf but appeared upon suckling. There was no immediate appearance of agglutinins in the blood of milk-fed calves. It is thought that the augmented immunity reaction may be accountable in part for the observed resistance of the colostrum-fed calf to invasion by *B. coli*.

Retention of fetal membranes.—It was found by the Minnesota station that in healthy cows the fetal membranes are, as a rule, expelled within 4 to 6 hours. When retained for more than 10 or 12 hours it is evidence of placentitis. Involution is seldom completed inside of 30 days. Retention of the fetal membrane retards involution and often causes inertia of the uterus, which may result in infection. Normal involution acts as a barrier to infection.

Paratyphoid dysentery of lambs.—A result of slow and improper handling of stock in transit is the incidence of fatal diseases of various kinds. A serious outbreak of paratyphoid dysentery in lambs was found by the Colorado station to be due to delay and improper feeding in shipment. Out of 30,000 lambs involved in the delayed shipments, approximately 2,000 died. The organism was isolated and the disease reproduced in normal lambs. Fasting lambs were found to be much more susceptible to the disease than those properly fed.

Swellhead of sheep and goats.—Investigation by the Texas station indicates that this disease has a direct relation to malnutrition or deficiencies in the feed or diet. The disease does not occur in flocks receiving supplemental feeds but is not uncommon when the animals are grazed without any other feeding. Treatment with Glaubers salts followed by a mixture of nux vomica, gentian root, and aloes gave good results.

Reliability of the tuberculin test.—Studies by the Minnesota station indicate that slight and atypical reactions to tuberculin should not be taken lightly or ignored. Cattle giving such reactions are very likely to give positive reactions or positive autopsies later. Nontuberculous cattle may be unusually sensitive to tuberculin and some may be artificially sensitized by its use, especially in ophthalmic work. Marked discrepancies between tests and the large percentages of unsatisfactory tests occurred in either repeatedly tested herds or in badly diseased herds.

Avian tuberculosis.—A steady increase of swine tuberculosis, as shown by abattoir statistics, is attributed, by the Nebraska station, in great part to infection of avian origin. Of 209 cases of tuberculosis in swine examined by the station, 185, or 88.5 per cent, were avian. Inoculation of guinea pigs alone was found to be insufficient for diagnosis. The station therefore suggests supplementing the microscopic examination with inoculation of both guinea pigs and fowls to detect the avian form. Tuberculin of mammalian origin often fails to detect avian tuberculosis and vice versa. Both avian and mammalian tuberculin should therefore be used in diagnosis. Mammalian tuberculosis is more virulent than avian in swine.

The selection of safe quarters and feed, the rejection of carcasses as food for swine, and above all the practice of hog lot sanitation, such as is now generally advocated for the prevention of the filth-borne pig diseases, are recommended as the best means of controlling the disease.

Yearling calves exposed to the droppings of tuberculous chickens were found by the North Dakota station to be readily sensitized to avian tuberculosis, as evidenced by positive reactions by both intradermal and subcutaneous tests with avian tuberculin, but not with bovine tuberculin. Pigeons and sparrows similarly exposed showed no infection. Feeding tuberculous organs from chickens to rats and barn and field mice failed to produce infection.

Calves injected with avian tubercle bacilli developed local lesions and gave good positive tuberculin reactions, with the intradermal test, in experiments at the Wyoming station. The local lesions resembled greatly those observed in the skin form of tuberculosis. The organisms were found to be alive and active in the lesions eight months after they had been introduced. They could be entirely removed by surgical operation and five months afterwards the calves failed to react.

Less than 1 per cent of the eggs from tuberculous fowls was found by the Minnesota station actually to contain living tubercle bacilli. No tubercle bacilli were found in or on the eggshell.

Fowl typhoid and cholera.—The North Carolina station concludes that there are morphological differences and differences in physiological reactions of the causative organisms of the widespread and destructive diseases fowl typhoid and fowl cholera that differentiate them as due to separate and distinct germs. The clinical symptoms, blood changes, and pathological anatomy of the diseases are sufficiently unlike to establish a basis for differential diagnosis. However, control measures that apply to avian typhoid should be effective in checking the spread of avian cholera.

Prevention of coccidial infection in chickens.—The California station found that feeding cultures of *Bacillus acidophilus* to chickens resulted in the implantation of the organism in the ceca. The pH value of the cecal contents was changed from the normal range of 6.0 to 7.4 to a range of 4.4 to 5.6 by feeding sufficient amounts of whole sweet milk, milk cultures of *B. acdiophilus*, milk cultures of *B. acdiophilus* plus lactose, lactose alone, or dry skim milk. Feeding chickens a mash containing 40 per cent dry skim milk not only protected them against coccidial infection, but also stimulated rapid growth.

Condensed buttermilk diluted with water and kept before the chicks was found by the Texas station to be of value in reducing losses from chicks infected with coccidiosis.

Roundworm in poultry.—The thymus gland of baby chicks parasitized with the large roundworm (*Ascaridia perspicillum*) showed less than half the development of that of unparisitized chicks, in experiments at the Kansas station. The amount of sugar in the blood of the parasitized chicks became decidedly subnormal. Eggs of this nematode placed on the surface of the soil during the winter months were less viable when in the infective (coiled embryo) stage than when the eggs first left the bodies of the chickens. Many of the freshly laid eggs survived freezing temperatures.

Control of internal parasites.—The Michigan station has developed a colloidal suspensoid state of iodine which appears to be not only ideal for disinfecting poultry houses, sow-farrowing pens, and the like, in a 0.2 per cent suspension in water, but is also a highly efficient vermicide for the treatment of stomach worms of sheep and intestinal worms of poultry when administered in connection with some vehicle for carrying iodine to the worms, such as milk and Epsom salts.

Stomach worms of sheep are, according to the Connecticut Storrs station, more effectively controlled by iodine (Lugol's solution) than by tobacco dust, nicotine sulphate, or copper sulphate. The iodine solution kills both the mature and immature worms. It can be used to kill the immature worms in lambs and pregnant ewes if necessary, but it is better to treat pregnant animals early in pregnancy, unless they show marked symptoms of stomach worm infection. The treatment used was drenching lambs over 30 pounds in weight with 4 ounces of a solution made by adding 0.5 ounce of Lugol's solution to 1 quart of water and repeating this treatment once every 4 weeks. For older sheep each animal was drenched with 4 ounces of a solution of 1 ounce of Lugol's solution in 1 quart of water and repeating the treatment at 4-weeks intervals from June to November, inclusive.

Anthrax.—The Louisiana station found anthrax spores in various parts of plants growing on infected soil, thus indicating that such plants may be carriers of the disease.

Poisonous plants.—White snakeroot, Eupatorium, is reported by the Illinois

station to be a common cause of what is knownas trembles in cattle, horses, and sheep in the Mississippi Valley. The plant generally grows in woodland pastures, reaching maturity in August and September. The trouble generally appears during late summer and autumn especially when other vegetation is scarce because of drought. Horses, cattle, and sheep grazing in pastures where white snakeroot is found may be fatally affected. The plant is occasionally fatal to man, and in case of recovery there is a long period of convalescence and often lasting debility. Pastures known to be infested with the plant should not be used for animals during the late summer or fall. It can be elimated from pastures by persistent pulling every year.

The wild chokeberry was found by the Nevada station to contain hydrocyanic acid in fairly large quantities. Range losses from this plant are confined to cattle and sheep. It is eaten only when there is a shortage of other vegetation, and loses are most common, therefore, on overgrazed areas. The leaves are most poisonous during spring and early summer, heaviest losses occurring at this time. Animals do not develop a tolerance for the plant, and no effective remedy has been found.

In feeding experiments with dried material of *Lupinus argenteus*, the Wyoming station found that it took large amounts of seeds and pods to produce any toxic effect on sheep. Three pounds of seed or 4.4 pounds of the pods per hundredweight was required to produce serious symptoms, and under ordinary conditions the sheep would not eat enough to produce harmful effects. The lupine was found to contain an oily substance more deadly than the crystalline alkaloids.

FOODS—AGROTECHNY

Composition and nutritive value of corn.—The Illinois station made a notable contribution to the subject of foods during the year in the publication of a bibliography of work on the composition and nutritive value of corn and its products. The extent of investigation on the subject is indicated by the fact that the bibliography occupies nearly 150 closely printed pages. A large proportion of the references is to American work.

Wheat flour and bread.—Factors affecting the milling and baking quality of wheat flour are being studied by a number of stations. Some recent station contributions to this subject are as follows:

The North Dakota station found a positive correlation between protein content of wheat and the percentage of dark, hard, and vitreous kernels and the baking quality of the flour and between test weight per bushel and flour yield but not loaf volume and absorption.

Cool storage of wheat for two years showed no harmful effect on loaf volume or baking quality, and possibly an improvement, in experiments at the North Dakota station. There was some deterioration in warm storage. The Utah station found that highly milled flour made from sound wheat could be stored in dry rooms free from odors for at least four years without deterioration, but that low-grade flour and that made from whole wheat deteriorated under the same conditions during this period. The bread making properties of flour increased for a time in storage. The percentage of soluble amino nitrogen decreased. The moisture content of the flour as well as of the wheat tended to approach a constant of 8 per cent. Water-soluble phosphorus increased during storage, due apparently to cleavage of the phospholipins of the flour. Soluble carbohydrates increased, whereas acidity decreased at first but later increased. The rate and extent of increase varied with the flour, being more rapid and greater in poor grade flours than in high grade.

Milling was found by the Utah station to remove 70 per cent of the ash, 63 per cent of the calcium, and 79 per cent of the magnesium of wheat. The calcium-phosphorus ratio in the wheat was 1 to 2.2 and in the flour 1 to 3.8.

Yeast fermentation of doughs was accelerated by the NH_4 ion and by phosphates, in experiments reported by the Minnesota station. Very small quantities of the aluminum ion were found to be very effective in increasing the capacity of the dough to retain carbon dioxides. Wheat sprouted for three days under controlled conditions and added to flour increased its diastatic activity and improved the baking quality. Lactic and acetic acids were the only organic acids found in flour preparations fermented with yeast, lactic acid to the extent of about 75 per cent of the organic acids present, and acetic acid 25 per cent.

Proteins of cereals.—The Minnesota station found the prolamines from emmer, einkorn, spelt, and durum to be closely related to gliadin and glutenin from wheat, those from teosinte and kafir to zein from corn. The former appeared to be more closely related to gliadin than to glutenin, while the protein from teosinte was more closely related to

zein than was that of kafir. No reactions were obtained between antisera for the corn group with proteins from the wheat group, and conversely. A simple, accurate, and direct method for the preparation and quantitative determination of glutenin in wheat flour which may also be applicable to the study of the glutelins of other cereals and so be useful in determining their bread making qualities.

Food value of grain sorghums.—The grain sorghums are largely used as food in certain parts of the world. The Oklahoma station found in experiments with rats that grain sorghum seed sustained life and appeared to contain a sufficient amount of food accessory substances. The protein substances, however, are nutritionally incomplete.

Food quality of potatoes.—As a result of analyses of several hundred carefully selected individual potatoes, the Colorado station found no two of identical composition in the same variety, in the same group, or even in the same hill. The quality of the potatoes appeared to depend "more upon grower, soil, and season than upon variety." Steamed or baked potatoes were found to contain less water and consequently more of the other constituents—carbohydrates, nitrogenous matter, and ash—than boiled.

Edible canna starch.—Manufacture of starch from the edible canna has been shown to be practicable by the Hawaii station. The canna starch is characterized by exceptionally large grains and hence is recommended for infants and invalids. Morphologically it is similar to potato starch. "When cooked it forms a semitranslucent, rather sticky mass, such as is characteristic of potato or arrowroot starch but different from the opaque gel obtained from cornstarch."

Deterioration of sugar.—The Louisiana station showed that by protective inoculation of cane sugar with torulae not only was the keeping quality greatly improved but there was also great improvement in the color as well as the physical condition of the sugar crystals. Treated sugars were much less hygroscopic than untreated, owing to loss of levulose and lost moisture in storage, whereas untreated sugars absorbed moisture. Sugars having a torulae content of 1,000,000 per gram of film did not deteriorate.

Jelly making.—The enormous waste of surplus fruits has led to widespread efforts and to find more efficient and profitable ways of utilizing this surplus. One of the means receiving much attention by both the Department of Agriculture and a number of the experiment stations is jelly making. The Colorado station published during the year a comprehensive bulletin on the making of fruit jellies, based on extensive investigation, which describes the methods necessary to secure jellies of assured quality and standard grade.

The Delaware station, studying more in detail the factors controlling the jellying of fruit juices, found that, other factors remaining constant, the strength of jelly is dependent upon its pH value and not upon total acidity. The strength of jelly at the optimum pH value varied with the kind of acid used. With a given quantity of pectin and acid the optimum strength point was determined by a rather definite amount of sugar. Increasing the sugar beyond this point decreased strength, and decreasing it increased toughness. The point of optimum jelly strength was reached when the amount of sugar used formed a saturated solution, the amount of pectin and acid remaining constant. For a given quantity of pectin and sugar at a constant pH value, the strength of the jelly increased with the concentration of pectin. The strength of jelly decreased consistently with the time of boiling the pectin-acid solution before the addition of sugar but varied only slightly with the time of boiling the pectin-acid-sugar solution. The strength decreased with increase of temperature and increased with age. Regardless of total acidity or presence of salts, the minimum point of jelly formation occurred at a pH value of from 3.50 to 3.35. The optimum point of jelly formation varied between the limits of 2.85 and 3.30, depending upon the nature of the acid and salt used. Total acidity may vary over a wide range, depending upon the buffering power of the initial solution from which the jelly is made. The strength of the jelly, made by adding a salt to the pectin-acid-sugar solution, was found to be dependent upon the initial pH value of the solution and the concentration of the salt.

A method of determining pectin by titration of the acidity developed on saponification with sodium hydroxide was reported by the Missouri station. This is based upon the fact that under constant conditions the amount of pectin is proportional to the acidity developed. Electrometric titrations of pectic acid precipitated by hydrochloric acid from the saponified pectin showed 11 carboxyl groups, but apparently saponification

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was not complete, since the composition of pectin as shown by combustion indicated 12 such groups. On the basis of 11 free carboxyl groups and 1 unsaponified group the molecular weight of pectic acid is estimated to be 2,138.

To get the clear pectinous fruit juice necessary for a brilliant clear jelly of desirable consistency the Oregon station found that the fruit should be parboiled at a temperature not exceeding 212° F., to increase the solubility of the pectin, and the juice extracted under pressure while still hot. Juice obtained with heat and pressure was found to be richer in pectin than that which flowed off freely. Filtration with the addition of clarifying agents and under pressure if required was necessary to obtain a clear juice. Concentration in vacuum is recommended for juices that are to be stored.

Concentrated fruit juices.—Concentration in vacuo was found by the California station to be the most practical method for concentrating fruit juices, although concentration by freezing preserved the color and flavor of the fresh juice better. It did not, however, yield so high a concentration as vacuum concentration. It was found that the aroma of the fresh juice lost during concentration could be recovered from the condensate by redistillation and returned to the concentrate. Excellent concentrates were made from the juice of oranges, lemons, grapes, pomegranates, apples, raspberries, and loganberries, and other blackberries. Strawberry concentrate lacked color, but it was possible to make up this deficiency by the addition of blackberry concentrate. This station also found that juice concentrated in vacuum at a low temperature retained practically all of the antiscorbutic value of the original juice. Clarified concentrated orange juice retained this factor to a great extent, although it is probable that the longer exposure to the air at higher temperatures lowered it somewhat. Desiccated orange juice prepared by a spray-drying process retained a good proportion of the antiscorbutic value even after two years' storage. A dried whole orange product prepared in a commercial dehydrator proved to be a very concentrated source of the antiscorbutic factor. Concentrated lemon juice, commercially prepared by evapopation in vacuum at a low temperature, was also found to be a concentrated source of the antiscorbutic substance.

Sauerkraut.—Fermentation of sauerkraut, under ordinary conditions, is very variable and the product equally so. In experiments by the Wisconsin station on controlled fermentation, it was found that inoculation with selected cultures of lactic acid bacteria altered the normal flora of the kraut and gave an improved product. It reduced the number of foreign organisms and the duration of their existence in the fermentation. The inoculated kraut contained more lactic acid and less acetic acid and ethyl alcohol than the uninoculated kraut.

Vitamin content of milk of silage-fed cows.—Milk from cows fed grain sorghum silage was found by the Oklahoma station to be superior to that from stover-fed cows and to furnish sufficient vitamins for rats and guinea pigs when fed at rates of 10 per cent of the body weight, indicating that the vitamins of the sorghum were not destroyed by ensiling.

Effect of light on eggs.—The Kansas station found that eggs from hens receiving a large amount of ultraviolet light contained an abundance of the antirachitic vitamin, while eggs from those receiving a limited amount of the light contained only a small amount of the vitamin. Eggs from hens given cod-liver oil at the rate of 0.5 cubic centimeter per hen per day hatched as well as those from hens receiving direct sunshine.

Blackening of canned corn.—It appears from studies made by the Illinois station that the blackening of canned corn is not wholly due to the container but may be in part due to the condition of the corn at the time of canning. Application of acid phosphate to the soil at the rate of 1,200 pounds per acre greatly increased blackening, while use of 600 pounds per acre of potassium chloride decreased it. High-protein and high-oil field corn blackened much more than low.

Spoilage of tomato pulp.—The New York State station found gaseous fermentation, which is responsible for considerable losses in stored tomato pulp, catsup, and other tomato products, to be due to an organism to which the name *Lactobacillus lycopersici* was given. "Laboratory tests indicate that a temperature of 150° F. (65° C.) for five minutes or one of 170° F. (76° C.) for two minutes destroys the organism in catsup. Slightly longer exposures were needed in pulp. The organism is practically always present under factory conditions but is normally eliminated by proper processing."

Canning in acid brines.—In a study of the rôle of acidity in vegetable canning, the California station found that brines acidified with a small quantity of citric acid greatly reduced the heat resistance of the spores of heat resistant bacteria

and that if the decrease in pH value which occurs during heating is taken into account it is possible to sterilize canned vegetables much more easily in acidified brines than in nonacidified brines.

Botulism poisoning.—The Colorado station found that the organism *Clostridium botulinum*, causing botulism poisoning, is widely distributed in soils in form of spores which are highly resistant to heat. Strains of the organism were found whose spores were not killed by boiling for three hours at 212° F. Occasionally even more resistant forms were encountered, for example, one of which the spores were not killed by six hours' boiling at the altitude of Denver, Colo.

AGRICULTURAL ENGINEERING.

Notable progress was made at the stations during the year in the development of investigation in agricultural engineering.

MACHINERY

Tractors.—The California station found, in a continuation of its studies on the removal of dust from tractor engine intakes, that at least 90 per cent of the dust normally inspired by an air cleaner or carburetor could be avoided if the intake was placed high and faced away from the direction of motion of the tractor. A rearward opening acted as an inertia type dust separator. It was further found that in a service test involving several uncontrollable variables, no just comparisons can be drawn among air cleaners not differing greatly in efficiency. Frequent changing of crankcase oil and consequent maintenance of higher viscosity markedly reduced engine wear.

A method of determining the distribution and value of tractive impulse stresses in soils as delivered by the lug of a tractor drivewheel has been developed by the Alabama station. In this method the soil is placed in a box in uniform, evenly compressed layers, separated by sheets of very thin paper treated so as to offer a minimum resistance to shear. The layers are placed perpendicular to the soil surface and at right angles to a plane passing through the center of the entire rim of a lugged tractor wheel. The soil block is then placed in a testing machine and the wheel is run forward until the lug has passed through any desired amount of soil. The block of soil is then removed from the machine and the surface, lug imprint, and each successive layer of the soil is cast in plaster of Paris. Thus the entire soil block is accurately cast into component blocks, the surfaces of which conform to the distortions produced in the sheets of delicate paper by the tractor wheel lug. These casts are accurately marked into contours of equal distortion or pressure. The relative thicknesses of the casts at any point give a measure of the pressure at that point and the entire soil movement under impulse stress is visible and in a permanent form for study.

Plow draft.—Heavy manuring of silt-loam soil seemed to increase the draft of plows slightly in experiments reported by the Missouri station. Chemical fertilizers, even in heavy applications, did not increase the draft. Within a range of moisture conditions satisfactory for plowing there was a tendency for the draft to increase as the moisture content decreased.

The plow draft on different soil types varied with different soil treatments in experiments at the Illinois station. The addition of organic matter to a soil tended to reduce the power required for plowing.

Disk harrows.—By the proper arrangement of gangs, the California station found it possible to obtain a disk harrow which tills a strip of land, the center of which is offset from the center of the tractor as is required in orchard cultivation. Such a harrow, while operating off center, does so without side draft upon either the harrow or the tractor. Only one position behind the tractor was found where a given disk harrow, operating under specific conditions of gang arrangement, weight, speed, and soil, can do so without side draft. It was also possible to design a disk harrow in which the gang arrangement can be adapted to operation, without side draft, either directly behind the tractor or with a large right or left hand offset.

Plow metal.—Studies by the Alabama station suggested that the adhesion of soil to plow metal is due to the fact that the two materials are brought into such close contact as to permit the molecules of one substance to attract those of the other. Some indications were obtained that certain treatments of the metal materially affected the adhesion.

Draft of wagons.—The Missouri station found that the draft in pounds per ton of load of various kinds of equipment with different heights of wheels and widths of tires averaged the greatest for a cornstalk field, followed in order by muddy clay road, spongy clay road, bluegrass sod, burned clay or ballast, dry well-packed cinders, dry and firm clay road, dry packed macadam, dry well-packed gravel road, worn brick,

concrete in good condition, and new brick. Tests in cultivated land showed a saving in draft per ton of load by increasing the height of the wheels and the width of tires. The wagon with high wheels and narrow tires had about the same draft as the common low wheel, wide tire wagon. The convenience of the low-wheel wagon was taken to indicate its desirability for farm use. Neither the wheel height nor the tire width markedly influenced the draft on hard surfaced roads.

Silo fillers.—The Wisconsin station has developed a formula which indicates the maximum capacity of silage cutters with reasonable accuracy. Silage cutters were found to have much greater capacities than is ordinarily attributed to them. Machines with 18 or 20 inch cylinders were found to have much more capacity than any ordinary crew of men can supply. This was taken to indicate that larger machines are unnecessary, and that machines of these sizes can be operated at speeds approximately 40 per cent slower than at present recommended and still have sufficient capacity for ordinary requirements.

Threshers and harvesters.—Studies of the efficiency of grain separators by the Illinois station showed that man labor is used more efficiently with basket racks and with small threshing rigs. Blanket tests on 20 machines showed that the grain loss could be reduced below 1 per cent by proper machine adjustment and better feeding except where the loss was caused by damp grain. The Utah station found the losses from 12 harvester threshers surprisingly low. In most cases the loss from headers equaled that from combines, and in addition the stationary thresher gave a loss of about 1.75 per cent.

A thresher for single heads of grain for laboratory use in plant breeding work was developed by the California station. In this the threshing cylinder is mounted directly on the motor shaft. No toothed concave is used, thus making it possible to use higher tooth tip speeds without cracking the grain. Sloping bars are inserted in the housing to prevent any possibility of whole heads being blown by without being hit by the cylinder teeth. The threshing cylinder and its teeth constitute the only blower, and the blast is entirely adequate to remove the chaff.

Seed wheat treating machines.—Studies at the Oregon station on mechanical equipment for the treatment of seed wheat with copper carbonate dust resulted in the development of a diagonal axle machine using a barrel or steel drum for a container, fitted with a mixing board placed diametrically across the barrel two-thirds of the way back from the door. It was found that in treating machines of this type the mixing action will cease and the grain will be held against the drum walls by centrifugal force at from 48 to 50 revolutions per minute. This maximum speed was not influenced by the quantity of grain in the drum. The best speed of operation was found to be about 30 revolutions per minute. A microscopic examination of the grain at each tenth revolution showed that at 10 revolutions each grain was coated, but rather unevenly. At 40 revolutions the coating of dust was complete, smooth, and even. Any further turning merely smoothed out the coating. The conclusion was drawn that the sliding and rolling action of the grain in this type of machine is very effective in giving a quick and even distribution of dust in an adhering coat.

The most common fault of the seed wheat treating machines used in the State was found by the California station to be their inability to prevent the escape of dust into the air. Every batch mixer tested coated the seed satisfactorily if operated long enough. The most efficient quantity of grain to use at each treatment in a batch mixer was found to be that equal in volume to from one-fourth to one-third of the volume of the mixing box. A rotary barrel type churn was found satisfactory when filled about one-fourth full and turned slowly. It was necessary for the grain to fall from end to end or from side to side of the churn in order to obtain the best results. A tight box mounted on a shaft and revolved slowly by hand or mechanical power was also satisfactory. Batch mixers were found to be in general of too small capacity and to require too much labor to be satisfactory for warehouse and ranch use.

In general, it was found that the design of the interior of the continuous revolving mixers may differ very widely, with a correspondingly wide difference in effectiveness. The results indicated that the baffles should be so placed as not to hinder the outflow of the treated grain too much, and that the height of any baffle should not exceed one-sixth of the diameter of the revolving cylinder. The speed of operation which required the most power and produced the most violent tumbling about of the grain gave the best results.

Continuous gravity type mixers were found to require less of the coating material than most other types. The capacity depended upon the width,

breadth, and height of the vertical chute. It was necessary for the slope of the inclined baffles to be steep enough to cause the grain to fall readily and the machine to clean itself completely. Dusted grain lodged on a much steeper slope than untreated grain. When a proportioning device was used the feed of dust was found to be irregular and the coating of the grain not uniform.

Seeding machines.—The California station found that, with the same setting of the seeding indicator on several types of grain drills, the quantity of seed in the hopper did not affect the rate of seed delivery until the seed shells were exposed. Neither the operation or nonoperation of the agitator nor variations between ordinary high or low field speeds had any effect on the rate of seeding. There was considerable variation in the rate of seeding of different varieties of wheat. The treating of wheat with copper carbonate dust caused the rate of seeding to decrease from 5 to 37 per cent, depending on the variety and quality of the seed. Large plump varieties gave the largest decrease in rate of seeding when treated with copper carbonate dust, especially when planted at low rates per acre.

STRUCTURES

Crop storage.—The Illinois station found that tile ventilators were slightly more satisfactory than A-frame ventilators in cribs 8 feet wide and 10 feet high containing corn with 43 per cent of moisture. The most economical method of drying corn with forced air was found to be that in which unheated air is blown into a special ventilator in the center of an open crib.

The temperatures inside an apple storage house, with no means of mechanical refrigeration or heating, tended to follow prolonged outside conditions, in experiments at the Indiana station. The humidity of the air of the storage rooms was easily maintained at approximately 90 per cent saturation, with 80 per cent as a minimum, regardless of outside changes. Temperatures could be reduced by natural draft to as low a degree as by forced ventilation, but not so quickly.

The main problem in the development of common storage for eastern apples is, according to the Massachusetts station, to provide some means for producing and maintaining temperatures as low as 40° F. or less in cellar storages in the early storage season. This was accomplished by the use of ice either with or without salt to hasten the cooling and either with or without insulation against ground temperatures, as was found necessary.

Sweet potatoes can be kept in excellent condition in adobe storage houses until late in the spring, according to the Arizona station. The advantages of the adobe storage house were found to be cheapness of material, simplicity of construction, and high insulating properties.

Poultry houses.—The Iowa station found that the ventilation of poultry shelters is primarily a winter problem in which relatively low temperatures must be considered and in which excessive humidities must be dealt with instead of the low humidities existing in human shelters. Comfort is maintained when the heat produced by normal body combustion approximately balances the radiation necessary to maintain a fairly constant body temperature. Extremely low temperatures were found to reduce egg production, whereas high temperatures accompanied by excessive humidities caused discomfort, inactivity, and loss of appetite, and increased the susceptibility to bacterial invasion. Indications were noted that air purity as measured by carbon dioxide content is probably secondary in importance to temperature, humidity, and rate of air movement.

Egg production in a house heated with a brooder stove exceeded that in an unlined, fully ventilated house, and the increased production exceeded the cost of heating, in experiments reported by the Nebraska station. A house which was lined but unheated gave almost the same egg production as the heated house. Lack of ventilation during the night did not appear to affect the egg production adversely.

Livestock shelters.—Investigations at the Iowa station on masonry arch barn construction, involving the design, construction, and testing to destruction of a 36-foot reinforced concrete and clay block arch with a rise of 24 feet 7 inches, showed that the arch as designed on the basis of available structural principles was much stronger than required. The stress required to cause failure was equivalent to the pressure created by a wind velocity of 160 miles per hour. The results indicated both the possibility and practicability of building a barn wholly of masonry.

Silos.—Studies at the Iowa station to develop a satisfactory treatment for making silo walls impervious showed that bitumen or asphalt applied so as to insure a good bond was the most satisfactory treatment. All attempts to use plaster coats of various kinds

were generally unsuccessful. Silo storage capacities were found to vary widely from year to year, due primarily to differences in the water content of the silage and to a less extent to the weight of the grain.

Dairy structures.—Investigations at the California station on milk houses for California dairies indicated that concrete is an ideal material for the foundations and floors, all floors to be laid on a well-drained surface at least 4 inches above the ground level. It was found inadvisable to have an outside entrance to the milk room but to enter from a vestibule or wash room in order to prevent the entrance of flies. Window glass surface equivalent to 10 per cent of the floor area is considered sufficient to admit the necessary sunlight.

IRRIGATION

Soil moisture capacity.—The Washington station found that the water holding capacity and rate of water penetration in six soils were very uniform. These soils held as much as 3.5 inches of water per foot of depth when saturated in the field and 2.5 inches per foot under conditions of equilibrium after being thoroughly irrigated. This indicated that the upper 6 feet of soil will hold 15 inches of water before any loss by percolation occurs. It was further found that the soils must contain 0.5 inch per foot in order to have any water available for crops. Irrigation of from 2 to 3 inches every 20 days was necessary to keep them restocked with water during the irrigation season where there were no crop demands.

In the determination of the moisture equivalent, the California station found that the smaller the sample the larger the percentage of water retained. Some clays were found to become impervious to water during centrifuging when the quantity of soil placed in the centrifuge cup was increased, and these soils reabsorbed the supernatant water when the centrifugal force was relieved. The moisture content was found to increase from the inner to the outer surface of a 60-gram block of soil, but the rate of increase was lower than that resulting from reducing the size of sample from 60 to 5 grams. The apparent specific gravity of a 60-gram block of soil was found to be significantly greater than that of a 10-gram block, and decreased continuously as the size of sample was decreased from 60 to 10 grams. The apparent specific gravity within a 60-gram sample increased significantly from the inner surface outward to a point about 6 millimeters within the sample, beyond which it remained substantially constant to the outer surface. The placing of weights on the inner surface of 5-, 10-, 20-, or 30-gram samples decreased the quantity of water retained. Subjecting the soil to centrifugal force until the moisture was in equilibrium resulted in the establishment of an equipotential region throughout the block of soil. In general, it was found that the average pore space did not limit the quantity of water retained by the soil block.

Water losses.—The Colorado station showed that under still air conditions the rate of evaporation decreases as the difference between the temperatures of the air and water increases. The maximum rate of evaporation was found to occur at about sunrise in the laboratory and during the afternoon under fully exposed conditions.

Soil mulch had an inhibitory effect on moisture absorption, in experiments at the Washington station, when individual rains were not of sufficient volume to fully penetrate the mulch. This was due to increased evaporation of the newly fallen rain. There was a greater total loss of moisture from mulched soil when conditions favored evaporation than from unmulched soil.

A correlation between ground-water supply and the transpiration losses in a cottonwood and mesquite forest under different conditions of temperature, humidity, and cloudiness, and stages of leaf growth was observed by the Arizona station. The daily fluctuations of the water table caused by the transpiration of trees and by recharge of the water supply were large, sometimes exceeding 5 inches.

Duty of water.—The California station failed to correlate the use of water by prune trees with any particular percentage of available soil moisture. On the contrary, a continuous need for available moisture from the beginning of spring activity to dormancy in the fall was indicated. Depth of ground water below the soil surface must apparently be considered along with other factors in fixing the economical field duty of water. Widely varying the time and amount of irrigation was found to have no appreciable effect on the root development of alfalfa receiving uniform total applications of water.

Irrigation pumping.—Tests of fuel oils for pumping by the Arizona station showed that under the new process of cracking the crude oils now used by some refineries, the volatility of California cracked oil distillates is higher in relation to their specific gravities than that of

straight-run distillates. The cracked oils appear to have the same qualities as straight-run oils of 3° B. higher gravity.

Irrigation structures.—Studies of the Venturi flume at the Colorado station showed that with the 1-foot flume a marked degree of submergence is possible before the discharge is reduced from that of the free flow due to the formation of a hydraulic jump within the structure. It was found that the degree of the resistance to submergence increased as the width of the throat increased. The allowable degree of submergence was from 70 to 75 per cent for the smaller flumes and from 75 to 80 per cent for the larger sizes.

Alkali soil treatment.—Black alkali was found by the Arizona station to resist leaching tenaciously, and could be removed from the soil successfully only after neutralization. The percolation of water through very fine sand or fine sandy loam soil was accelerated by gypsum treatment. The acceleration increased with the amount of gypsum applied, at least up to double that necessary to neutralize the black alkali present.

Leaching alone was effective in removing the neutral salts from impervious black alkali soils, in experiments at the Oregon station, but was not effective in removing sodium carbonate or in improving the physical condition of the soil. Leaching and drainage in connection with chemical treatment were necessary in order to remove the neutral salts resulting from the decomposition of sodium carbonate. The value of heavy gypsum, sulphur, and alum treatments was indicated.

DRAINAGE

Grouud-water level.—Studies of ground-water level by the North Carolina station showed that the character of the soil rather than topographic features is the determining factor in the rise and fall of ground-water levels under similar drainage conditions. The ground-water level between tile lines in a level soil of uniform texture was found to rise in a smooth curve from the tile lines to a point midway between them. This curve may be very irregular in a soil of irregular texture. The rate of drop of the ground-water level midway between tile lines at a 3-foot depth in Norfolk sand averaged from 1 to 1.7 feet per day in the surface foot and from 0.5 to 0.75 foot in the second foot. The ground-water surface between the widely spaced drains commonly used in muck soils was found to be comparatively flat, and the rate of drop below the surface 18 inches was very slow.

Run-off.—Gaugings made by the North Carolina station on a typical dredged Piedmont creek indicated that the drainage factor used in computing channel sizes for drainage improvements of this type should be increased to 1 inch per 24 hours as compared with 0.5 to 0.75 inch per 24 hours formerly used. The ratio of run-off to rainfall was found to vary from 33 to 54 per cent, with an average of 45 per cent.

Records of discharge from farm tile drainage systems obtained by the North Carolina station indicated that a run-off coefficient of from one-third to three-eighths inch per 24 hours will give satisfactory results under average conditions of soil and spacing of laterals. Where surface water inlets are used, this should be increased to 0.5 inch. It was further found that a 1-inch rainfall will be absorbed by an open soil drained by tile to a depth of 3 feet without any run-off where the ground-water surface is at the level of the drains prior to the rain.

Drainage structures.—In experiments on the maintenance of drainage canals in the Coastal Plain, the North Carolina station found that where the depth of water in the canals was considerable throughout the year there was little growth in the channel. Where the canal was large for the quantity of water carried, resulting in a shallow normal depth of flow, conditions were favorable for a heavy growth of vegetation. The most favorable season for clearing the channel of plant growth was found to be between June 15 and August 1.

A spacing of 120 feet with a depth of 3.5 feet may be used for the more open Coastal Plain soils, according to the North Carolina station, with the same beneficial results and a saving in cost over a spacing of 100 feet with a depth of 3 feet. Silt was not deposited in 4-inch laterals when laid in a sandy clay subsoil on a 0.3 per cent grade. Experiments in substituting tile of large diameter for open ditches showed that tile sizes up to 18 inches in diameter are practical when supplemented by a sufficient lateral system and surface water inlets.

Drainage by pumping.—Investigations by the California station showed that the cost of drainage of irrigated lands by the pumping method compares favorably with that of any other method yet tried. More effective drainage was possible by the pumping method than by the use of tile or open drains, because of the flexibility of the pump-

ing system and the greater depth to which it is economically feasible to lower the water table. The pumped water was found to be readily available for irrigation and to compensate in part for the cost of drainage by this method.

SANITATION

Sewage disposal.—Studies by the Illinois station of the design of farm septic tanks showed that the two-chamber tank yields the purest effluent. Better digestion of solids, as indicated by sludge accumulation and solids passing out, was also obtained in this tank than in single or three-chamber tanks. A 48-hour retention period was found to be superior to the 24 and 72 hour periods.

In a continuation of studies on the biology of sewage disposal, the New Jersey stations observed a rise and then a fall in sludge digestive activities in Imhoff tanks. High amounts of ammonia were found to correspond with low percentages of carbon dioxide production. The carbonates reached the peak shortly after carbon dioxide and ammonia. There was in general an inverse relation between carbon dioxide production and H-ion concentration. Apparently the H-ion concentration gives a true index of the total activities taking place in a tank. Different types of digestion appear to dominate at different times in Imhoff tanks. Indications were obtained that the protozoa of Imhoff tanks may afford a fair criterion as to proper working conditions.

An apparent relation between the total bacterial numbers, total animal life, percentage of carbon dioxide in the gas, and the pH values of the effluent of Imhoff tanks was observed by the New Jersey stations. When the tank liquid registered a pH value below 7, the solids rose and foaming occurred, when it rose slightly above the neutral point the foaming subsided and the scum receded. Fresh solids, contaminated with partially digested material, were found to pass through a course of digestion similar to that of uncontaminated fresh solids, there being, however, a marked difference in the rapidity of digestion.

A seasonal fluctuation of fungi, which reached a maximum during the winter months, was observed in sprinkling filters at the New Jersey stations. Film removal studies showed that, when this process started, several species of protozoa increased rapidly in numbers, there being apparently a succession of groups. When fungi became more abundant the large numbers of free-swimming protozoa disappeared.

Water supply.—The Colorado station found distillation to be the only method by which alkali water may be satisfactorily purified for drinking purposes. It was possible to distill such water from 10 to 15 per cent cheaper with coal than with artificial gas.

A well may be safely located from 50 to 100 feet from a privy vault, cesspool, septic tank, or sewer line in ordinary soil, according to the Illinois station, but a greater distance may be required in gravel, sand, or open soil. Gravity water supply systems were found to be satisfactory for many farms, although apparently the hydropneumatic system is more generally satisfactory. Studies of different types of electric water systems indicated that the actual efficiency of such equipment is low, and that many could be operated with greater economy. It required from 15 to 25 per cent more power when the range of working pressures was from 20 to 50 pounds than when it was from 10 to 20 pounds. The latter range was found satisfactory under practically all conditions.

POWER

Use of electricity from central stations.—Investigations of the electrical hatching of chicks by the Oregon station showed that the power was on for only very short intervals of time in each individual incubator. The power utilization during the first day was relatively high on account of the initial heating of both the incubator chamber and the eggs. The daily consumption then remained constant at 4 kilowatt hours per day until the fourteenth day, at which point it decreased, due to the utilization of the latent heat in the egg by the growing germ. From that time on until the chick was hatched the power consumption gradually decreased, reaching a low point of 1 kilowatt hour per day at a room temperature of 65° F. The room temperature was found to materially affect the power consumption and should not exceed 95° in order to obtain economy of time in the egg cooling process. An average temperature of from 85 to 90° proved to be the best. Ventilation became inefficient in the incubators tested when the room temperature was raised to 85 or 90°.

The electrical energy required to run milking machines in seven dairies was found by the California station to vary from 0.033 kilowatt hour to 0.145 kilowatt hour per day per cow, and from 0.16 to 0.5 kilowatt hour per 100 pounds of milk.

The average number of farm users of electricity per mile of distribution line in 10 representative areas of the State was found by the Oregon station to be 4.17, the most extensive use being for lighting and household conveniences. It was concluded that the cost of electricity per kilowatt hour will depend largely upon the volume of use, and that aside from household appliances, pumps, and some dairy machines, the agricultural equipment at present available is not adapted to the electric drive.

The greatest appreciation of electric service by Kansas farmers is for illumination according to the Kansas station. The demand for the electric brooder on farms appeared to be wider than that for the electric incubator. The use of electricity for pumping was found to offer greater promise of building up a rural electrical load than any other single service. Grain binding, elevating, shelling, and cleaning appeared to offer the best field of general farm development in motor belt work, while ensilage cutting and threshing if generally motorized must compete with the tractor. Possibilities for a general utility motor were indicated, but the use of electric motors for drawbar work was considered to be as yet wholly in the experimental stage. Electric milking machines were also found to be in the developmental stage, particularly for the smaller dairy farms. The average farm user of electricity consumed but little, if any, more current than the urban user, and line and transformer losses on many rural lines exceeded the amount of current used.

The best method of bringing electric service to the farm is, according to the Minnesota station, that in which the lines are built by the public utility and paid for by the consumer on an actual cost basis, with due consideration for degree of benefit obtained. It was further concluded that service charges should be based on a low rate with a fixed minimum charge.

Individual electric plants.—A home-lighting plant propelled by wind investigated by the Indiana station had a capacity to produce an average daily output sufficient to light the average farm home and also to operate such appliances as a sewing machine or vacuum cleaner.

The cost of electric current from isolated farm electric plants was found by the Virginia station to be exceedingly high. It appeared that, over a period of time, the cost of current from the nonbattery type of plant is lower than that from the battery type.

A fuel economy test by the Missouri station on a typical nonbattery automatic light plant showed that there was very little difference between the cost of operation for a small load and that for a large load, and that if the plant is operated at all, lights as large as from 150 to 200 watts might just as well be used.

MATERIALS

Binder twine.—Tests of binder twine by the Indiana station showed that the average tensile strength for most of the brands tested was above the guaranty, but that lack of uniformity in both tensile strength and thickness of the twine was the cause of breaks. The tensile strength was found to be directly proportional to the number of fibers in the twine and the number of fibers was of greater importance than their length. It was further found that the thickness of binder twine is not always an indication of its strength, since loosely twisted twine allows fibers to slip, causing the stress to be carried by individual fibers.

Concrete.—In cooperative studies with this department on the effect of immersing concrete and sand mortar cylinder specimens for one year in lake water containing from 2.34 to 4.72 per cent of a combination of magnesium and sodium sulphates, the Minnesota station found that none of the high alumina cements used showed evidence of any deterioration. None of the standard Portland cement cylinders cured in steam at a temperature of 212° F. showed any surface action of the lake water, regardless of the length of time they were so cured. Curing in water vapor at temperatures of 155 and 100° was found to be of no value. Considerable deterioration was evident in all cylinders cured in the laboratory in the moist closet, followed either by further curing in water or by storing in air, or both.

Beet pulp was found to have a destructive effect on both mortar and concrete by the Colorado station. This was not great up to 150 days of pulp storage, but increased progressively for longer periods.

Roofing materials.—Studies of the durability of prepared roofing by the Iowa station indicated that exposure to the sun is one of the most important deteriorating factors.

The tensile strength of bituminous materials was found by the Alabama station to decrease markedly as a rule after exposure to the weather for one year. The time required to break

down under a flame test also decreased in the majority of cases after exposure, although the sheathing surface appeared to retain its resistance to heat better than the weathering surface. However, exposure to the weather seemed to increase the temperature at which flowing began. Exposure seemed to decrease the tendency to absorb moisture, but to increase the volatility.

Fence posts.—The Missouri station found that setting wood fence posts in gravel and charring did not pay, and that painting with hot carbolineum was perhaps better than painting with creosote. Double tank treatment with creosote was the most effective, the 5-hour treatment being better than the 2-hour. It did not pay to treat some varieties, particularly honey locust, willow, cottonwood, and white oak, unless the whole post was treated. Black ash, sassafras, red oak, and ironwood made good posts if given the double tank creosote treatment. The Iowa station found that cottonwood, willow, and elm fence posts which were given a good creosote treatment 17 or 18 years ago are still in service and in good condition.

LAND CLEARING

Stone removal.—The Wisconsin station showed the mud-capping method of rock blasting to be entirely satisfactory for breaking ordinary rocks and bowlders. The total cost of rock blasting was considerably higher when holes were drilled into the rock than when the mud-capping method was used.

Brush removal.—The Minnesota station found the average number of man hours required to "brush" an acre to be 32.4. Cutting brush in the late summer to prevent sprouting back was considered to be a practice of questionable value under ordinary farm conditions. It was found that sheep must be starved down to the pasture to do any real good from the standpoint of brush removal. The Alabama station found that the cost of brushing varies from one-half of the final cost in light timber to one-eighth of the final cost in heavy timber, and that in complete clearing the cost of brushing is about twice as great for pulling as for blasting.

To use a sprout mower, the Missouri station found that the stumps must be cut low so that they will not interfere with the machine frame or slow up the beater chains. The machine should be used the first year after the timber is removed, as second year growth is too large for effective operation. At least two strippings per year are necessary.

Stump removal.—The Minnesota station found that stumps may be removed by blasting at least one-third more cheaply when the soil is full of moisture than when it is dry. Forest fires were found to be more effective than four years of decay in reducing stumping costs. Stumps that were dead, partially decayed, and burned were cleared with a smaller expenditure of man and horse labor than stumps that were green when burned. The cost of postfire clearing of stumps was only about half of that of prefire clearing.

The final cost per stump is about the same for pulling as for blasting, according to the Alabama station. The best results in blasting were obtained when the charge was placed at a depth of twice the diameter of the stump and 14 inches from the base. This was especially important in the case of stumps 15 inches and over in diameter. Other conditions being equal, the efficiency of blasting was found to be in direct proportion to the amount of free water in the soil up to the point of saturation. Best results were obtained in loosening stumps by blasting while under tension from the puller. Heavy blasting before pulling generally did not reduce the quantity of soil on the roots on removal.

ECONOMICS AND SOCIOLOGY

Adjustment of production.—A number of studies on the adjustment of agricultural production and its adaptation to market demands were reported by the stations during the year. A food consumption, production, and distribution survey of Charleston, W. Va., and its trade territory was reported by the West Virginia station, which showed soil and climatic conditions adapted to the production of potatoes and various truck crops, melons, fruits, meats, milk, butter, cheese, eggs, and poultry, for which there is a large demand in the local market. The importance of catering to the demand for products of higher quality than are now supplied the market is emphasized. A similar study was made by the Virginia station of local products consumed in the city of Roanoke. There is a growing demand at good prices for meat, dairy and poultry products, feed, truck crops, and fruit which can be grown to advantage locally. More efficient production, higher quality, and better adjustment to the market requirements are emphasized. A study of the present status and market outlet of fruits, truck crops, and poultry in Atlantic County, N. J., especially to supply the local market

demand, was reported by the New Jersey stations. Adjustment of production to market demand is somewhat restricted. Market facilities are improving and further improvement might be possible through adoption of a pooling system of handling the products. The advantage of growing a smaller number of better quality crops on each farm is suggested.

A study was made by the New Hampshire station of the present production, sales, and methods of marketing farm products of farms in Cheshire County, chosen as typical of changes that are taking place in agricultural production throughout a large part of New Hampshire and New England, which showed that the number of farms and the production are decreasing, and costs of transportation of food commodities are increasing. Except for the supply of whole milk, apples, bush fruits, and sweet corn, the county does not feed itself. Dairying is the basic farm industry. The average cost of feed for milk production on 40 farms with 5 or more cows per farm was $1.49 per 100 pounds, or 60 per cent of the average price received at the cooperative milk plants. The advantage of permanent plantings of apple trees on favorable sites is indicated, as is also timber production. An expansion in the total acreage of vegatables is held to be inadvisable, although commercial potato production with machinery on 10 or more acres may prove profitable.

Economic studies of milk production.—Further reports on studies of dairy farming in New York were published by the New York Cornell station. These dealt with costs and returns in production of milk of different grades, on different farms, and under varying conditions of organization and management.

In a study of production of grade A milk, with and without cash crops, on farms in Chenango, Onondaga, and Cortland Counties, the average labor income of the farms without cash crops was $299, on those with cash crops $1,065. The cow cost of producing milk in the first case was $2.59 per 100 pounds, in the second $2.79. The cow costs per pound of butterfat were 72 and 80 cents, respectively. Outstanding features of some of the more successsful farms were high yield of cows, high yield of cash crops, and intensive methods of management.

On farms in Madison County producing grade B milk with alfalfa roughage, the average net farm income in 1921 was $997 and the labor income $228, in 1922 $783 and $4, respectively. The net cow cost of producing milk in 1921 was $2.50 per 100 pounds and in 1922 $2.54. The cow cost per pound of butterfat was 74 cents in 1921 and 75 cents in 1922. In 1921 the average loss was $19.87 per cow and 32 cents per 100 pounds of milk, but after all charges except those for labor were met the returns were 13.9 cents per hour for all time spent on the enterprise. In 1922 the average loss was $20.65 per cow and 35 cents per 100 pounds of milk. The returns were 16.1 cents per hour for the time spent.

On 121 farms in northern Chenango and southern Madison Counties carrying 2,749 cows and producing grade B milk with cash crops and mixed hay roughage, the cow cost of producing milk was $2.56 per 100 pounds. The cost per pound of butterfat was 76 cents, and the labor income per year was $321. There was a loss of 46 cents per 100 pounds of milk produced. Some of the factors of success of the more prosperous farms were productive cows, economical feeding, and good prices for milk and cash crops.

In an economic study of the production of milk for factories making Limburger and whole-milk Cheddar cheese on 67 farms in Jefferson County, N. Y., the station found that the cow cost per 100 pounds of milk sold was $2.45, while the average return was $1.63, excluding calves, hides, and manure. The labor income was minus $374. The farms on which this study was made are devoted almost exclusively to dairying. "Very few farmers in this area are getting ahead financially. Few farms are sold. The disappearance of hay markets with the coming of motor transportation has taken from these farmers their only cash crop. This means that the system of farming must be changed."

The low average returns from 22 dairy farms studied by the North Dakota station were found to be due mainly to the poor quality of the cows kept. Comparing two farms, otherwise similiar, one of which kept scrub cows, the other good grade or purebred cows, it was found that the annual net income per cow was $33 in the first case and $68 in the second, the butterfat produced per cow being 146 pounds in the former and 300 pounds in the latter. The extra 154 pounds of butterfat was responsible for the profit of the second farm. If the latter had produced no more than the first farm it would have been operated at a loss.

Successful dairying in Vermont.—Of the factors which enter into the succesful management of Vermont dairy farms, as indicated by correlation coefficients between the several factors and labor

income on 189 farms, the Vermont station found the most important to be quality of cattle and the economic employment of labor. On efficient management in these two respects rests largely financial success or failure. The station therefore emphasizes the importance of keeping only cows capable of large production and of giving careful attention tothe planning and execution of the farm work.

Cost of beef production.—From a detailed study of the cost of finishing 1,558 steers for the market in the period 1913–1922 in Hancock County, Ill., the Illinois station found the average cost of adding 273.7 pounds of gain to be $52.83. Marketing charges were $2.87 per steer, and the finished animal, weighing 1,167.9 pounds, represented a total cost of $124. The net selling price was $113.90 and the net profit, allowing a credit of $12.17 for by-products, was $2.07 per steer. The results on different farms varied, however, from a profit of $12.60 per steer to a loss of $14.50 in the same year. During the 10 years covered by the study, feed cost was 85.5 per cent of the total feed-lot costs, man labor 4.1, and interest 4 per cent. General farm expense was 2.9 per cent, horse labor 1.81, buildings 0.82, miscellaneous 0.21, and death risk 0.66 per cent.

From data obtained from 23 farmers fattening 993 head of cattle, practically all the feed being home grown, the Minnesota station found that the cost per 100 pounds of beef laid down at the market varied from $5.87 to $9.37, and the price received varied from $5.64 to $10.36. The feeder who received $10.36 for his beef made the most profit per head, and the one with a net cost of $5.87 per 100 pounds laid down at the market made $10.23 profit, which was more than the average. The feed required to produce 100 pounds of gain was 693 pounds of grain, 318 pounds of silage, 409 pounds of roughage, and 7 days of pasture. The labor to produce 100 pounds of beef was 0.27 of a man hour and 0.17 of a horse hour.

In a study of the cost of producing beef animals on California ranches during the period October 15, 1923, to February 1, 1924, the California station found that the costs of producing calves to the end of the first year after birth varied from $22.47 to $58.70, the average being $38. The cost to the end of the second year averaged $56.31, ranging between $32.83 and $88.04. The net cumulative cost of producing a steer to the selling period in the fourth year at an average age of 44 months was $108.69. The cheapest gains were made in the second year, the gains being relatively small thereafter. It is deemed most profitable to dispose of all beef animals before the beginning of the fourth year. Feed and labor, including management, constituted 59 per cent of the cost of raising a calf to the end of the first year, which increased to 67, 71, and 73 per cent, respectively, during the following 3 years.

Cycles in hog prices.—Studying the period from 1911 to 1924, inclusive, the Nebraska station found evidence of distinct cycles in hog production and prices. An unusual number of spring pigs were farrowed in 1907, 1911, 1915, 1918, 1922, and 1923. In December, January, and February following each of the large pig crops, an unusual number of hogs were marketed and hog prices fell. The number of spring pigs farrowed in 1909, 1913, and 1920 was below normal. The number farrowed in 1917 was much larger than in 1909 or 1913, but was considerably less than the average of the war-time period. Each of these small crops sold at a relatively high price per pound. Each period of good prices stimulated production. It is believed that a farmer may so regulate his own production that he will receive the advantage of the recurring periods of high prices, and that wisely regulated production and thoughtful marketing will go far toward stabilizing hog prices.

Cost of growing apples.—The Ohio station found the total cost per tree during a 10-year period to be $5.69 for orchards under cover crop and $3.35 for orchards under grass mulch, or counting only the trees living at the end of the period $5.89 and $3.75, respectively. The average income per tree for the period was $6.51 for the cover crop orchard and $6.91 for the grass mulched trees.

Cost of cotton production.—The more important factors which determine the yield and hence the cost and profits of cotton production were found by the South Carolina station to be mule and man labor for cultivation, fertilizers, and damage by the boll weevil. Yields of less than 200 pounds of cotton per acre cost about 7 cents more a pound than higher yields. Man and mule labor costs were correlated to a considerable extent with the acre cost of cotton, but on a pound and total production basis heavy use of labor usually paid. Analyzing the farm business as a unit, it was found that an average farm income of $378 was obtained by the operators of the 333 farms included in the study. The owners made a higher farm income than the tenants. The average labor

income was minus $392. The large farms made more than small ones; owners made larger farm incomes but smaller labor incomes than tenants.

Specialized onion growing in Iowa.—The Pleasant Valley onion district of Scott County, Iowa, is an example of successful crop specialization, in striking contrast with the typical Corn-Belt farming prevailing in that State. Approximately 500 acres are devoted exclusively to continuous onion growing, the average size of farm being about 10 acres. The Iowa station found in a survey of the district that it requires 220 hours of man labor and 62 hours of horse labor to produce, harvest, and market an acre of onions. About 50 per cent of the total man labor is required during August to harvest and market the crop. The total crop is approximately 200,000 bushels annually, and it is produced during nine open months, leaving the winter months unoccupied. Home-grown seed is almost exclusively used and the crop is marketed immediately after harvest. This is an example of a type of farming which provides a living probably equal to that of the Corn-Belt farm with only part-time employment. However, it is a highly specialized business requiring a special type of person with an inclination toward intensive farming to be successful. The opinion is expressed that onion growing will succeed best as a community enterprise, and that it is not likely to be followed on the average Corn-Belt farm because the nature of the work and the care needed for onion production differs widely from that of the Corn-Belt farms.

Size and organization of North Dakota farms.—Records obtained by the North Dakota station from 159 owner operators covering their farm business for the year ended March 1, 1923, showed the average size of farm operated to be 817 acres, ranging from 160 to 3,600 acres. The farms of most frequent occurrence were from 320 to 960 acres in extent. Approximately 34 per cent of the farm area was devoted to wheat. Land represented 81 per cent of the investment, its average value being approximately $20 per acre. Livestock, including work horses, amounted to 8.6 per cent of the investment and machinery slightly over 5 per cent. The average farm income was $1,692, ranging from $1,112 on small farms to $2,300 on large ones.

The best size of farm for the region appears to be about 800 acres, with approximately one-third of the acreage devoted to crops, one-half of the crop area being devoted to wheat, about one-sixth to oats and barley, and from 7 to 10 per cent to corn. Flax may be substituted for wheat to a limited extent, and alfalfa, sweet clover, and millet are important minor crops. For farms of the most common size, about 10 milch cows and double this number of other cattle are considered to be advisable, and the better organized farms with about 275 acres in crops require 9 work horses.

Farming systems in Iowa.—Studies made by the Iowa station in Warren County showed that in 1921 crops occupied 59 per cent of the farm land and pasture 37 per cent. Of the land in crops, 45 per cent was in corn, about 30 per cent in small grain, and the remainder in hay. Hogs comprised the most important class of livestock. Less than 20 per cent of the gross income from these farms in 1921 came from crops. Practically 25 per cent was realized from this source, however, in 1915 and 1918. About one-third of the total income came from hogs in 1921. The three outstanding items of cash expenditure in 1921—taxes, purchased feed, and hired labor—constituted 17, 14, and 12 per cent, respectively, of the total chargeable expense. The most profitable cropping system for this area is thought to be one with as little pasture as the soil and surface conditions of the farm justify and as much corn as can be produced without reducing yields. Wheat is the most profitable small-grain crop. Most of the corn crop is utilized in feeding hogs, although there is some cattle feeding on the larger farms, and many of the farmers combine a limited amount of dairy production with the general cattle enterprise.

Farming in the black-land cotton belt of Texas.—A study by the Texas station of conditions on 500 farms typical of the black-land cotton-farming belt in Rockwall County showed that in 1922 90 per cent of the land in the farms studied was improved, and of this 93 per cent was devoted to crops, of which cotton made up 67 per cent. Of the investment in farm capital 94 per cent was in land and permanent improvements and 6 per cent in machinery and livestock. Of the 500 farms, 450 hired labor at an average expenditure of $346.38 per farm. Loans for various purposes amounted to an average of $1,111.34 per farm. Of the amount borrowed 71 per cent was used for buying land and the remainder for making a crop and for living expenses. The net income per acre was found to be closely correlated with a number of factors,

particularly the yield of lint cotton per acre.

Organization and management of West Virginia farms.—Approximately three-fourths of the farms of the State are general or diversified farms, according to the West Virginia station, and as a rule are too small for profitable general farming. About one-half of the tillable area of the farms is under crops. The tendency is to increase the size of farms. The net cash income, not deducting interest, was found to vary from $147 on medium-sized general farms to $2,106 on large livestock farms. "Labor incomes were fairly high on the large livestock farms only, the average being $1,388 per farm. The next highest average labor income per farm, $499, was on the truck farms. Four groups of farms made minus labor incomes; the average farmer of these groups received nothing for his own labor and less than 5 per cent interest on his investment. The family incomes, or money available for the family living and paying interest, did not exceed $471 per farm on the general farms, and it was not less than $754 per farm on any other type. The outstanding improvements needed on a very large majority of the farms studied, were a larger farm business and a better utilization of labor. * * * Farming in West Virginia has become essentially livestock production and will likely remain such." Improvement of pastures is therefore of paramount importance.

Irrigation farming.—In a study of irrigation farming in Gallatin Valley, the Montana station found that the average labor income was $555 in 1913, $1,501 in 1918, minus $731 in 1919, minus $2,098 in 1920, minus $1,268 in 1921, and minus $96 in 1922. In every year the labor incomes covered a wide range, both above and below the average, and the comparative profitableness of individual farms from year to year was very inconsistent.

The results of a detailed survey of a typical small reclamation project in Elko County, Nev., made by the Nevada station in the spring of 1924 showed that of the 31 families living on the project all owned land and some operated additional land owned by the company. The average total acreage farmed was 173 acres. Potatoes and dairying are the chief sources of income. The annual receipts from crops averaged $461 and from sales of livestock $368 per farm. The receipts from livestock products, principally cream, amounted to $703. The labor income averaged $753 per farm. The value of home-grown foods used by the family was $441, and the cash paid out for groceries was $311 per family.

Marketing potatoes.—From a study of private potato marketing agencies and farmers' cooperative organizations at country points in western and northern New York, the New York Cornell station concludes that the farmers' cooperative associations, single-station dealers, and many-station dealers supplement one another and that their competition encourages the best efforts for efficiency and economy. The lack of proper accounting is one of the weak features of the business.

Creameries and cooperative milk shipping stations in North Dakota.—In 1923 there were, according to the North Dakota station, 1,235 cream stations, 1,209 of which were operated by centralizer creameries and independent cream buyers and 26 by cooperative cream shipping associations in North Dakota. One-third of these have been very successful. The average value of equipment of the cooperative stations was $452, and the average operating expense $1,822 per year. The successful stations handled an average of 76,527 pounds of butterfat and had an average membership of 105.

Chicago milk market.—The Illinois station found a tendency to overproduction of milk in winter and a shortage in late summer and early fall in the dairy regions contributing to the Chicago market. Distribution in the city was studied with special reference to its equalization and better utilization of the available milk supply. In the winter of 1923 the average daily sale of milk in one of the wealthier sections of the city was 1.65 pints per family, in nine poorer sections it was 1.96 pints. The estimated daily per capita consumption of milk was 1.01 pounds. The demand for dairy products varied with the season, the day of the week, and the temperature. These variations are fairly definite and can therefore be predicted. There was a certain amount of surplus that must be carried at all times because of the variability of supply and demand, but this necessary surplus is a cost of the business and should not unduly influence prices. It is especially unfortunate that a large amount of surplus milk comes in the winter, when production costs are high.

Marketing apples in Massachusetts.—The Massachusetts station found that it cost $1.15 per bushel to market the 1923 crop in certain typical apple-growing sections of the State. Sale to buyers was shown to be the least profitable method of sale. Sales on commission returned the highest average prices and

the highest average margins over cost of marketing. The importance of grading was emphasized in this study.

Labor required for threshing.—The Illinois station found that in central Illinois approximately 11 hours of man labor was required to thresh 100 bushels of oats and 20 hours to thresh 100 bushels of wheat. In Franklin County, approximately 18 and 25 hours, respectively, were required. It is held that under favorable weather conditions and with efficient management 100 bushels of oats can be threshed with 6 hours of man labor and 10⅔ hours of horse labor.

Use of tractors on Ohio farms.—From a 5-year survey study of tractors which were being used an average of 256 hours per year, the Ohio station estimated the tractors to have a total life of 1,794 hours, or, on the basis of the amount received for tractors disposed of, a working life of 1,703 hours. The average hourly cost of operating 2-plow tractors was estimated at 93 cents and of 3-plow tractors $1.41. The use of tractors was found to have brought about a reduction of 1.3 work horses per farm in western Ohio and 1 work horse per farm in eastern Ohio. A reduction in the quantity of feed fed to each remaining work horse was also possible. In western Ohio there was an actual reduction in the combined cost of power and labor per crop acre following the purchase of tractors.

Farm mortgage loans in Texas.—Farm mortgage loans were found by the Texas station to run from 1 year in the case of the commercial banks to more than 30 years in that of Federal and joint-stock land banks. A relatively low percentage of the mortgage loans was used for the immediate purpose of buying land and improvements. From 6 to 9 per cent of the mortgage was used to pay off short-time indebtedness. Approximately 62 per cent of the mortgage loans of commercial banks was arranged to be paid off in one payment at the maturity of the loan, 46 per cent of those of insurance companies, 92 per cent of those of trust companies, and 38 per cent of farm mortgage companies.

Permanent occupancy of farms in Iowa.—In a detailed survey of 385 farm homes and farm families in Hudson, Orange, and Jesup consolidated school districts, the Iowa station found that in general about 75 per cent of the young people intended to remain on the farm, and from 55 per cent in Jesup to 94 per cent in Orange district of the tenants who did not own land indicated that they expected to become farm owners.

Insanity among farm women.—Replies to an inquiry sent by the Ohio station to superintendents of the State hospitals for the insane in Ohio tended to refute the popular opinion that farmers' wives, because of alleged monotony of their lives, are more subject to insanity than women in other vocations.

Rural population groups in Missouri.—In a study of rural population groups by the Missouri station in Boone County, which was chosen as typical of the greater part of rural Missouri, 59 primary population groups (neighborhoods) and 15 secondary groups (communities) were found. Primary group consciousness varied from high to low-minus, owing to local factors. "It was highest in those neighborhoods which were some distance from a community center and in those in which the opportunities for social contacts were greatest. The school was found to be the strongest factor in the maintenance of primary group consciousness. Intergroup consciousness was developed best through the consolidated high school, followed by the church, the lodge, and the store. Neighborhood boundaries were cut across in the efforts of the people to reach preferred points for such service as church, trade, school, lodge, and blacksmith shop. Thus a farm family has at a given time a number of separate and conflicting group loyalties." As a result the neighborhood is losing much of the force it once had. This is being transferred to the larger community, which usually includes a town or village. This larger rural grouping is new and now has less vitality and intensity of group consciousness than the neighborhood, although it appears to be on the gain, and will be of increasing importance in the development of rural affairs. "The status of a community depends upon physical, economic, and social factors which in a few cases are entirely beyond the power of the community to modify. The future of most community centers depends upon the ability to render superior service to the adjacent farm population. The negro primary groups are gradually becoming less intense in their social solidarity due to the competition of the larger community centers."

Family income and cost of living in a small factory town.—From a study of the income and cost of living made by the New York Cornell station during the year ended August 31, 1919, in the small factoy town of Groton, N. Y., it appears that the average family income for the year was $2,013.43. Of this amount the husbands contributed 75.5

per cent, the wives 13.8, the children 2.2, and other members of the family 0.5 per cent. The remaining 8 per cent consisted of receipts from farms, gardens, and livestock. The average cost of living for the year studied amounted to $1,659.30 per family, or $615.83 per adult male individual. The percentage of total cash income saved increased with the family income. The 92 families saved 13 per cent of the cash income received, the average per family amounting to $246.18. It is shown by comparison that even with a 33 per cent increase in earnings for certain New York City families they could hardly hope to save as much as did these families in the small town.

Rural store credit.—In a study made by the New York Cornell station it was found that most of the rural stores carried a large number of book accounts, few running higher than $100, together with a relatively small number of notes, most of which were for $50 or more. Implement stores, as a rule, carried a considerable number of notes. The greater portion of the notes taken by country merchants from their customers were discounted at the local bank, with the exception of the few cases in which notes on farm implements were carried by the manufacturer. The average net cost of credit for all feed stores, including paid and unpaid labor in keeping records, the cost of office supplies and collections, and the loss from bad accounts, was $1,507 per store; that for general stores was $549. The ratio of credit costs to total sales varied from 2.23 per cent for general stores to 3.85 per cent for farm-supply stores, the average for all being 2.83 per cent. The ratio of credit costs to credit sales is said to indicate that credit customers should pay an average of about 5 per cent more than cash customers.

INVESTIGATIONS ON TOBACCO, WITH SPECIAL REFERENCE TO QUALITY

By Henry M. Steece, *Specialist in Agronomy*

The pioneer efforts in experimental work with crops were aimed toward increased acre production and means of cultivating greater areas. This attitude persisted until a comparatively late date. Recently there has been excess production of certain crops, and the large surpluses depress the prices received by the grower who can not market his crops profitably. Indeed, the increased yields over a certain point may not suffice to pay for the additional cost of production. With a decreased demand for the lower grades of the product, the better qualities or grades stand out. In recent years plant breeders and other agronomists have endeavored to produce a better product or one possessing an outstanding quality. Increase in the protein content of wheat, variation in the oil or protein content of corn and of oil in soy beans, better brewing quality in barley, increase of the sugar content of sugar beets, quality and length in cotton fiber, flax, and hemp, improved seed value of potatoes, and the various demands for quality in leaf, type, burn, etc., of tobacco have called for elaborate investigations.

Tobacco, a conspicuous crop cultivated for both quality and yield, has been grown in the United States for over three centuries. From about 1,500,000 to nearly 2,000,000 acres have been devoted to tobacco in recent years and have produced a total of from 1,250,000,000 to 1,500,000,000 pounds. This country leads the world in total production and also in the number and diversity of distinctive types produced. A high degree of specialization has accompanied the rather steady expansion in acreage and production of tobacco during and since colonial days. Tobacco production has become definitely localized in each region because of the particular combination of soil and climate producing a distinct type suited for certain uses and differing in important characteristics from other types. The effects of soil and climate are said to be so marked that two regions will rarely produce exactly the same type of leaf.

A characteristic feature of tobacco culture as indicated by Garner et al. (*96*) [1] is that the acre returns to the grower commonly depend as much or even more on the leaf quality than on the yield, because of the wide range in prices for the different grades of leaf. The best returns are usually had from the highest yields of the finer grades of leaf rather than from maximum total yields. In such types as most cigar tobaccos and dark fire-cured and air-cured leaf, moderately high yields are usually associated with high quality. In other types, e. g., bright flue-cured, high quality of product so depends on the physical and chemical properties of the soil that high yields seldom accompany the best quality. In nearly all types of tobacco, rank coarse growth appears to be incompatible with high quality and and with maximum returns per acre. Therefore, highly intensive methods involving enrichment of the soil are limited in their application to tobacco culture.

Investigations at the State experiment stations, often in cooperation with the United States Department of Agriculture, having for their objects either the improvement of the quality of tobacco or increasing the yield, are indicated in the following pages. Varietal trials, entomological studies, and minor cultural and fertilizer tests, while of undoubted value, have been omitted in the review. The work of the experiment stations on tobacco prior to 1900 was dealt with in considerable detail in an earlier contribution from this office (*94*).

CLIMATE

Climate, an important factor in the distribution of tobacco cultivation in the United States, has a significant effect on the quality of the leaf. Good yields of tobacco of the best quality are generally produced under seasonal conditions tending to promote rapid unbroken plant growth.

Examination of climatic data and production statistics suggested that the yield of tobacco in Massachusetts (*41*) did not gradually decrease during the period 1910–1919. Low yields since

[1] Numbers in italics in parentheses refer to "References," p. 92.

1914 were due primarily to adverse climatic conditions. In general, rainfall seems to be the major limiting factor of growth (and this necessarily includes soil moisture), together with temperature. Excessive rainfall is invariably followed by a reduction in yield independent of temperature. Subnormal rainfall, accompanied by temperatures excessively above normal, reduces the yield, but with subnormal temperatures it does not apparently reduce the yield to any extent unless the rainfall is very much below normal.

SOILS

Tobacco can be grown in nearly every State in the United States, but certain soil types appear to be required for better qualities and superior flavor in the manufactured products. The physical and chemical properties of the soil decidedly influence the development of the characteristics of the leaf making its commercial value. From exhaustive studies of the relation of the soils to tobacco production, made by the United States Department of Agriculture (*91*), it was pointed out nearly 25 years ago that the light, sandy soils were used in Connecticut for the wrapper-leaf tobacco for domestic cigars and in Virginia and North Carolina for the bright yellow tobacco. Wrapper leaf is grown in the Connecticut Valley on a stony loam soil. In Ohio a filler tobacco for domestic cigars is grown on a gravelly loam; in Tennessee another gravelly loam type produced an export type of tobacco. The sandy loams in Maryland produce a smoking tobacco, in Virginia a manufacturing tobacco, in Connecticut a cigar-wrapper leaf, and in Pennsylvania a cigar filler. A fine sandy loam produces a cigar wrapper in Connecticut, and in North Carolina a bright yellow tobacco. The types of loam, silt loam, clay loam, and clay also produce a number of types of tobacco, according to the character of the soil and the climatic conditions.

Studies of the soil of experimental tobacco plats in Lancaster County, Pa. (*59*), with a comparison of analyses of typical tobacco soils, including those of Russia, of Sumatra, Java, Cuba, Brazil, Massachusetts, Connecticut, and North Carolina, led to the conclusion that, "despite the general impression that the best tobacco is grown only upon soil rich in organic matter, provided a proper soil texture and plant food supply be otherwise secured—a proviso shown by repeated experience to be entirely possible—the tobacco crop is practically independent of the presence of natural humus in the soil."

Tobacco soils were grouped by the Massachusetts station (*41*) as regards acidity or lime requirement. Soils requiring up to 3,000 pounds calcium oxide per acre do not produce good crops, as a rule, but are comparatively free from root rots; soils needing from 3,000 to 8,000 pounds calcium oxide are in good tobacco condition, but in this group pathogenic fungi, which may cause root rot during certain seasons, are abundant. Soils requiring over 8,000 pounds of calcium oxide are usually comparatively free from such fungi, even in unfavorable seasons, but may yield tobacco of slightly inferior quality. Although 2-ton applications of peat produced yield increase, it was deemed too expensive, and cover crops, especially timothy or rye, were recommended. Low-yielding soils responded favorably to organic matter and acid phosphate but did not show the lack of potash.

The pine lands have been considered to be the best tobacco lands in Maryland (*37*), and chestnut lands next, whereas oak and hickory lands were commonly regarded as poor tobacco soil. Varieties in Alabama (*1*) generally produced more cured tobacco on branch bottom land than on white sandy upland soil. The adaptability of the Willis and Huntsville, Tex. (*71*), soils to the growth of filler and wrapper tobacco has been reported on.

FERTILIZERS

Characteristic of tobacco is its rather large requirement for plant food for proper growth and the effect of the kinds of nutrients supplied on its quality. Besides the natural needs of the plant for plant foods, the finest qualities are grown on light sandy soils, which naturally have small amounts of plant nutrients and therefore must be heavily fertilized. The effect on quality of the leaf as well as the yield must be considered. The soil, seasonal conditions, the type grown, and local usages may affect the correct practices.

Extensive fertilizer experiments at the Connecticut State station (*10, 13, 14*) showed castor pomace to give more wrappers than cottonseed meal. Potassium-magnesium-sulphate led the potassium salts in production of wrappers and in total crop, whereas cotton hull ashes generally produced smaller crops than other potassium sources but made more wrappers. Linseed meal gave the greater wrapper yield, and the quality of the produce was better than

with cottonseed meal or castor pomace containing equivalent amounts of nitrogen. The quantity of wrappers increased regularly with the quantity of cottonseed meal or castor pomace applied. The yield of wrappers was greater when nitrogen was supplied only as castor pomace than when part was applied as sodium nitrate. The short wrappers differed somewhat in chemical composition from the long wrappers in further studies at this station (*15*). Differences in ether extract, fiber, and nitrogen-free extract contents were not traceable to the fertilizers used. Excessive nitrogen applications resulted in a much higher nitrate content and enhanced the protein and nicotine contents. The most potash was in tobacco receiving most fertilizer potash. In general the tobaccos having most lime had least magnesia, and vice versa. Comparatively large percentages of magnesia were found in tobacco receiving fertilizers containing much magnesia, which did not damage the quality of the leaf. The percentage of sulphuric acid in the leaf was very much larger when sulphates were used in the fertilizer, and the burn of tobacco receiving high-grade sulphate was very unsatisfactory. The ash of tobacco dressed with stable manure contained five times as much chlorine as the ash from any other lot in the series.

The plats of both shaded and unshaded tobacco receiving the largest quantity of lime at the Connecticut State station (*18*) showed a good deal of "white vein," the best unshaded tobacco being that receiving 1,000 pounds of lime per acre and of the shaded tobacco 2,000 pounds per acre. The results suggested that the use of lime may not, in all cases, have a deleterious effect on tobacco. Fertilizer experiments at the Connecticut tobacco substation (*8*) during 1922–1924 indicated that complete substitution of mineral for organic sources of nitrogen should be avoided and the quality of tobacco maintained. Mineral carriers may advantageously supply half of the nitrogen. Decided depression in yield and quality followed the use of excessive quantities of phosphoric acid. The use of potassium-magnesium-sulphate seemed without advantage where reasonably large quantities of organic fertilizer were applied. When the quantity of fertilizer was reduced the subsequent reduction in yield and quality more than offset the saving in fertilizer cost.

Investigations at the Georgia Coastal Plain station (*22, 23*), in cooperation with the United States Department of Agriculture, demonstrated the need of acid phosphate on new land, potassium starvation and breakdown of the plant resulting from withholding potash from the fertilizer, the beneficial effect on growth and quality of tobacco extending beyond the plant food in stable manure, and a considerable net increase in the returns from heavy as compared with medium or light applications of fertilizer. Nitrogen from several sources appeared better than from a single source. Better color (*24*) resulted where 1,000 pounds of 8–3–5 fertilizer containing 10 per cent of phosphoric acid was used than from 1,000 pounds with less phosphoric acid. Commercial fertilizers increased the total yields of tobacco in Guam (*25*) but not the percentage of marketable leaf. The continued use of lead arsenate spray and fertilizers on the same plats resulted in the highest yield and quality of tobacco leaves.

Commercial fertilizers materially increased the yield and improved the quality of Burley tobacco in Kentucky work (*27*) reported as early as 1890. Increase was had whether potash, phosphoric acid, or nitrogen was used separately or in combinations. Potash and nitrogen in combination seemed necessary for best results. The best combinations appeared quite profitable. Potassium either in the form of chloride or sulphate gave similar effects. Nitrogen as sodium nitrate seemed to produce the best quality of leaf. Later fertilizer trials with Burley in Kentucky (*34*) indicated that tobacco may respond to commercial nitrogen only where neither manure is added nor crop residue returned. Experiments on Lexington field, Kentucky (*30*), and elsewhere indicated that under some conditions in the central bluegrass region it is profitable to fertilize tobacco heavily with mixtures containing high percentages of nitrogen and potash in addition to phosphate, particularly in the absence of a good grass or clover sod or sufficient manure.

Nitrogen appeared to be the limiting factor on the soils, inorganic forms giving better yields than organic forms, with the reverse true as to quality, in fertilizer tests in Maryland (*39*) in cooperation with the United States Department of Agriculture. Phosphates did not increase yields but stimluated growth and promoted the proper ripening of the crop, resulting in a lighter color in the cured leaf. Potash gave only small yield increases on "rested" land, whereas soil continuously cropped to tobacco showed a decided need for potash. Liming produced increased yields of tobacco only when nitrogen

was not liberally supplied in the fertilizer. The darker tobacco following liming is said to be due to excess nitrogen made available. In previous Maryland experiments (*38*) high-grade potassium sulphate produced the best tobacco, and potassium carbonate furnished by cottonseed hull ashes the next best. Potassium salts containing either much chlorine or magnesium produced a tobacco of poor quality which cured badly and burned very poorly. Potassium sulphate produced a better burning tobacco than any other of the potassium salts in yet earlier trials in Maryland (*36*) whereas potassium chloride always gave tobacco with a poor burn and a bad ash, as did lime and magnesium compounds in most cases. Phosphoric acid did not degrade the burning qualities. Complete commercial fertilizer and manure produced tobaccos similar in burning qualities, and in most cases better than where no fertilizer was used.

In early cooperative experiments in Massachusetts (*40*) cottonseed meal, linseed meal, and castor pomace, with enough sodium nitrate or potassium nitrate to furnish one-fourth of the nitrogen needed, proved equally good as nitrogen sources for tobacco. Sodium nitrate with acid phosphate or dissolved boneblack, surpassed potassium nitrate under similar conditions. Cottonseed hull ashes and high-grade potassium sulphate proved the best potassium sources. Potassium nitrate gave good results when used with an alkaline phosphate or with potassium-magnesium-carbonate. Although 2 tons of peat per acre produced increased yields at the Massachusetts station (*41*), this form of organic matter was deemed too expensive, and cover crops, timothy, or rye were indicated. Low-yielding soils responded favorably to additions of organic matter and acid phosphate but showed no lack of potash. Soils showing normal growth in the young tobacco plant soon after transplanting were found by the Massachusetts station (*42*) to contain comparatively small amounts of total solids, nitrogen, potash, and of most water-soluble constituents, whereas soils giving abnormal results showed an increase of over 70 per cent of total solids, over 85 of water-soluble nitrogen, and over 219 per cent of water-soluble potash. The combined effect of the total mineral constituents of the soil seemed responsible for the injurious effect rather than an accumulation of any one of the soluble elements. Drainage and crop rotation were suggested as measures of possible relief.

Barnyard manure gave the largest yield in early tests at the New York Cornell station (*43*) but was not more profitable than commercial fertilizers. Potassium sulphate gave somewhat better results than the chloride. On Miami gravelly loam in New York (*46*) tobacco yields in an unmanured 4-year rotation of corn, tobacco, wheat, and clover were not maintained by commercial fertilizers alone in cooperative experiments. Nitrogen seemed to be a limiting factor on the soil, whereas liming greatly increased tobacco production which responded less to phosphorus and potash. On Miami silt loam in a rotation of tobacco, wheat, and two years of alfalfa, tobacco production was maintained better, although the production level was considerably lower than on the gravelly loam.

Magnesia derived from either dolomitic limestone or double manure salts and kainit applied fairly liberally generally eliminated sand drown in experiments at Oxford, N. C. (*54*), by the North Carolina station cooperating with the United States Department of Agriculture. Calcium alone seemed to hasten the exhaustion of the magnesia supply of these soils. Cottonseed meal, sodium nitrate, dried blood, and ammonium sulphate ranked in order as sources of nitrogen. Acid phosphate excelled as a source of phosphorus. Potassium chloride produced more and better tobacco than high-grade potassium sulphate, although all tests have shown tobacco produced with the latter salt to result in a better burning quality. Potassium chloride also demonstrated its superiority over potassium sulphate at Reidsville, N. C. (*52*), in affording protection against wildfire, producing better and larger growth and giving immunity from sand drown. An increase in the nitrogen content of the fertilizer at Reidsville (*51*) was followed by greater susceptibility to leaf spot and other diseases, whereas potash appeared to stimulate disease resistance.

Elaborate fertilizer investigations have been carried on by the Pennsylvania station (*58*) in cooperation with the United States Department of Agriculture. Experiments in York County, Pa., indicated that the tendency of the soils to produce high-chlorine tobacco may be largely overcome by avoiding chlorine-containing fertilizers and manure. The yields obtained from commercial fertilizers also showed the entire practicability of growing tobacco on these, as well as other soils, without manure. An experiment in Clinton County showed that the use of commer-

cial fertilizers containing their potash in the form of sulphate or carbonate gives tobacco of more certain burning qualities than does stable manure. The yield and quality of tobacco grown with stable manure alone as a fertilizer were also greatly inferior. Finally, there were indications that the cause of the poor burn can not be put on the chlorine alone. Improvement in quality and burn as well as yield was shown by tobacco from plats at Ephrata where cottonseed meal, acid phosphate, and sulphate of potash were added to the manure. Large quantities of nitrogenous fertilizer did not pay on the productive soils in Lancaster County. In previous Pennsylvania (*60*) trials application of cottonseed meal, potassium sulphate, and dissolved boneblack gave a better yield of uniform and lighter colored leaf than did manure. Substituting linseed meal for cottonseed meal apparently improved tobacco flavor. Horn meal instead of cottonseed meal and the partial replacement of cottonseed meal by sodium nitrate reduced both yield and quality. Ammonium sulphate as a partial substitute for cottonseed meal slightly improved yield and wrapper qualities of the leaf, but flavor and aroma suffered a marked deterioration. Where potassium-magnesium-carbonate replaced potassium sulphate the leaf was more uniform and of better texture and burned slightly better without impairing the flavor or aroma. Using basic slag and omitting phosphate resulted in a low yield with a poor quality of leaf.

Little difference was observed between sodium nitrate and cottonseed meal as sources of nitrogen for tobacco on Highland Rim soils in Tennessee (*69*). Six tons of farmyard manure per acre with 800 pounds of a complete fertilizer proved more profitable than either alone. Tobacco was not directly benefited by liming. Sodium nitrate and ammonium sulphate produced the greatest increases in yield of dark tobacco at Clarksville, Tenn. (*70*), and were the most profitable in a comparison of nitrogenous fertilizers. Definite need for potash was not shown in cooperative trials in Montgomery County.

Nitrogen was most effective in the form of dried blood in early Virginia (*72*) tests, and the nitrogen of sodium nitrate was found more available than that of ammonium sulphate. Complete fertilizer surpassed any incomplete fertilizer with tobacco in Pittsylvania County, Va. (*79*), and acid phosphate led the single element carriers in acre value. Increases in yield and quality of leaf followed heavy applications of fertilizers. Returns from tobacco were less on limed plats. Experiments with sun-cured tobacco in Virginia (*80*) indicated that a complete fertilizer containing a high per cent of phosphoric acid is essential to producing maximum yields of good quality tobacco, nitrogen being second in importance. However, potassium also seemed essential. For sun-cured tobacco satisfactory sources of nitrogen would be half from sodium nitrate and half from ground tankage. Lime was quite beneficial where ammonium sulphate was used and of slight value with sodium nitrate. The recent work has not shown potassium sulphate to be superior to potassium chloride for sun-cured tobacco. Since this tobacco is used largely for chewing, any adverse effect that potassium chloride would have on the burning quality is unimportant. The investigations suggest the application of from 1,000 to 2,000 pounds of 8–3–4 or 8–4–5 fertilizer to the acre for sandy soils unmanured, and about 1,000 pounds of 8–3–3 fertilizer on the heavier types of soil or where much manure is applied before the tobacco. Heavy applications of well-balanced fertilizers did not cause tobacco to fire or burn on the hill.

ROTATIONS AND COVER CROPS

The cropping systems followed in the producing districts differ to a considerable degree, according to the soil, local farming practices, and the type of leaf grown. Rotations were found profitable and maintained yields in Virginia (*76*, *78*) with dark tobacco, a rotation suggested being based on tobacco, followed by wheat, grass, corn, and cowpeas. The land could be left in grass for one or two years. Work in the sun-cured tobacco district in Virginia (*77*) recommended a 7-year rotation: Tobacco, wheat, grass, corn with crimson clover as a cover crop, cowpeas, and red clover. Crop rotations were also found necessary and profitable in this district. Declining yields in Virginia sun-cured rotations (*80*) seemed due to black root, possibly caused by growing cowpeas directly before sun-cured tobacco. Liming and heavy applications of fertilizer in the rotation resulted in increased yields. Results obtained with bright tobacco in Pittsylvania County, Va. (*79*), indicated that the tobacco rotation on bright tobacco farms should not include legumes and the soil should not be limed.

Burley tobacco in a 4-year rotation of wheat, clover and orchard grass, orchard grass, and tobacco in Kentucky (*34*) gave a considerably better

quality of leaf and average yields than where tobacco followed corn and other crops. In 3-year rotations, tobacco after a redtop sod was decidedly superior to that grown after wheat or rape. Manure on grass sod did not seem to reduce the quality appreciably in Kentucky (*32*). Poor yields and quality of leaf were obtained where soy beans were included in the 3-year rotations, this crop seeming to encourage root rot. Tobacco showed striking superiority on freshly cleared hardwood land as compared with old land at Reidsville, N. C. (*53*), and continuous tobacco was much better than that alternating with corn. Continuous cropping with tobacco was found dangerous at Oxford, N. C., especially where tobacco wilt prevails.

Closely allied to rotations is the use of cover crops in conserving and adjusting soil fertility and condition. Tobacco growers concerned with diminishing yields were urged by the Connecticut State station (*6*) to test timothy as a cover crop at least three years in succession as the only visible alternative to temporarily replacing tobacco with other crops. Tobacco yields at the Massachusetts station (*41a*) on plats having had a timothy cover crop were consistently lower than those without cover, and while the quality was about the same, a higher proportion of longer leaves was found in the no-cover crop. In another experiment, for four consecutive years the timothy cover consistently failed to increase yield and to improve quality. It seems that the timothy cover crop should be used cautiously by the tobacco growers, especially where the presence of brown root rot is suspected. *Vicia villosa* appeared to be a valuable cover crop for tobacco in both Connecticut (*4*) and Wisconsin (*82*). The relatively large amounts of chlorine taken up by broom sedge and pine from lands in Maryland (*37*), rested in order to reclaim them for tobacco, was held to explain the improvement of such lands for tobacco. Crimson clover early fall seeded on tobacco stubble and turned under in May greatly increased yield and quality.

BREEDING

Nearly all of the experiment stations working with tobacco have endeavored to improve the crop by selection, hybridization, or introduction of new varieties. Some of the genetic work with tobacco has been reviewed by the writer (*97*) in a previous report.

Investigations at the Connecticut State station (*21*) showed that, although environment is of prime importance in any system of tobacco breeding, and quantitative characters and, especially quality of cured leaf, are largely dependent on this factor, heredity is also significant, and poor types will give unfavorable results, even under optimum environmental conditions. The only known means of producing variability as a source of new types is by crossing. The number of new forms which will appear, due to a particular cross, will depend on the number of germinal characters by which the parent plants differ. Breeding work by this station (*5*) in cooperation with the United States Department of Agriculture and Harvard University showed that, as a rule, characters such as leaf size, leaf shape, number of leaves, and type of leaf, are inherited independently. An external similarity of size characters in tobacco varieties does not necessarily mean a genetic similarity. There seemed good reason for believing that quantitative characters are inherited in the same manner as qualitative characters. Quality of cured leaf is a complex character and due to many conditions, environmental as well as inherited. An added difficulty is that the quality of leaf must conform to trade ideals.

Selection did not result in better quality or yields in Ohio (*56*), whereas in the later generations of certain hybrids better than the parental yields were obtained. Study of certain hybrid strains indicated the possibility of breeding for special adaptations, such as drought resistance and a greater ability to utilize profitably the less available forms of plant food.

A cross at the Wisconsin station (*84*) of two strains, said to be mutants from common Connecticut Havana, gave rise to a strain said to possess considerable commercial value, the chief advantages being the quite erect rather broad leaves of uniform size from top to bottom of the plant, one or two leaves more per plant, with greater average size and a greater yield than ordinary Havana. The quality is said to be equal to that of Connecticut Havana. Improved strains of cigar tobacco have been developed by hybridization and subsequent selection at the Pennsylvania station (*58*).

SPACING AND TOPPING

Besides weather, soil, and the general characteristics of the tobacco plant, the

number of leaves grown on a unit area affects the yield. In experiments in Pennsylvania (*58*) high topping at 15 to 18 leaves resulted in the highest gross yields, and closer planting was more advantageous than normal planting. With the closer spacings in Wisconsin (*81*) the yield increased, the size and thickness of the leaves diminished, and the percentage of fillers increased. Tests on the Granville, N. C. (*51*), farm indicated that closer planting of tobacco can increase yields without injuring the quality. Plants spaced 16 inches apart gave the highest acre yields of filler, wrapper, and trash in Ohio (*55*). The decrease in yield and in total value per acre resulting from wider plantings was continuous. The closest planted tobacco was rather flimsy, perhaps because of immaturity and delayed ripening. During 1906 and 1907 suckering produced gains ranging from 193 to 340 pounds per acre over not suckering. Topping plants in full bloom a few weeks before harvest improved the crop in Connecticut (*3*) and made it ripen more evenly on the stalk. Leaf cured on the stalk was lighter in color and more papery and less elastic than that picked or primed before curing.

HARVEST

In studies at the Wisconsin station (*81*) of the influence of time of harvesting tobacco upon the yield and thickness of the leaf, the tendency of the leaf to become thick as the time after topping increases was more manifest in the leaves from the earliest topped plants. The thickness and dry matter of the leaf as well as yield tended to increase up to 32 days after topping. Zimmer Spanish tobacco harvested about four weeks after topping in Ohio (*55*) generally gave a greater total weight and higher percentage of filler and wrapper than when harvested three weeks after topping. Two strains of the wrapper type harvested in Pennsylvania (*62*) by priming produced considerably more than when harvested and cured on the stalks. The gain by primed crops seemed due to greater average maturity and smaller decomposition and loss in the curing of the primed leaf. These field grown tobaccos were far inferior in wrapper quality to shade-grown Sumatra and Connecticut Havana leaf. Priming also resulted in gains in yield in North Carolina.

SHADING

The culture of high quality cigar wrapper leaf under an artifical shade of cheesecloth or slats has been a comparatively recent development. The effect of shading on the leaf was observed in Connecticut (*3*) where about 9 pounds of unshaded Broadleaf were required to wrap 1,000 cigars, whereas only about 3 pounds of shaded Havana seed leaf and Broadleaf were needed. Shaded Broadleaf was not as elastic as open grown. Shaded plants grew slower than unshaded at the Connecticut State station (*18*) and showed the bud lower. After topping they produced unusually large thin leaves, were ready for cutting two weeks after unshaded plants, averaged less in weight, and their stalks were smaller and lighter.

Porto Rican (*68*) experiments indicated that shading increases the yield, quality, and percentage of wrappers enough to make the practice profitable, providing it is done only on soils suitable for growing wrappers and proper care is given the crop throughout growth and during curing and fermentation. A shelter tent experiment in Pennsylvania (*61*) proved that Sumatra leaf could be produced in Pennsylvania approaching the average imported Sumatra in color, luster, fineness of vein, wrapping capacity, and burn. A strain adapted to the Pennsylvania sandy loam and climatic conditions was developed. Shading tobacco with coconut leaves reduced yields at the Guam station (*25*), although more first-class leaves were obtained during the long, dry periods.

DISEASES

Although new tobacco areas have been opened up, the districts have been constant in location so that most soils are subject to continuous or repeated extensive culture. This naturally results in an accumulation of diseases and insects affecting tobacco in particular. Production of a good yield and high quality of leaf up to the manufacturing stage has been increasingly difficult in spite of the increased knowledge and experiences of the growers. Plant diseases, factors which cause average annual losses estimated to be about 5 per cent of the crop value or nearly $25,000,000 annually in the United States, have been studied by all the stations in the tobacco growing States. Although the literature is voluminous, space limitations compel the citation of but a single publication, compiled cooperatively by the Wisconsin station and the United States Department of Agriculture (*86*). The information assembled summarizes data largely obtained by the experimental activities and studies of the Connecticut State, Florida, Ken-

tucky, Massachussetts, North Carolina, Ohio, South Carolina, Tennessee, Virginia, and Wisconsin stations, and of this department, describes important tobacco diseases, gives the causal organisms where known, and outlines control methods.

Among the important diseases causing loss of plants are damping off or bud rot, sore shin, stem rot, black shank, Granville wilt, and Fusarium wilt. Black root rot, brown root rot, root knot, and broom rape are also responsible for stunted growth and losses of plants. Wildfire and blackfire, bacterial diseases which render the leaf ragged and deformed with consequent low value for manufacture of quality goods, are traceable to plant bed infection and like certain other diseases may be controlled by proper sanitary measures. Wisconsin leaf spot and frog-eye are of less importance in this regard. The losses from mosaic are a consequence of the reduced yields due to dwarfing of the plants and the mottling or abnormality of the leaves which render them unsuitable for use for certain purposes of manufacture. Frenching, often confused with mosaic, has leaf deformities and chlorosis also characteristic of mosaic. Typical of frenching are the numerous "shoe stringy" leaves.

A blanching or chlorosis of lower leaves on very sandy soil during seasons of excessive rainfall, known as sand drown, has been shown due to a shortage of magnesium in the soil or fertilizer. Certain adverse results also follow the lack of potash, nitrogen, and phosphoric acid.

After harvest the leaves are yet threatened by several destructive agencies. The conditions of curing, fermentation, and storage of the several types of tobacco must be most conducive to proper color, body, texture, elasticity, grain, burn, and other factors, composing quality for the separate types, and abnormalities during these processes are as important as those of the growing plant. The most common forms of damage in tobacco following harvest are shed burn or pole rot, stem rot, wet butts, white veins, must, and molds.

CURING

After harvest the tobacco leaf must undergo the curing process which consists essentially of a more or less rapid desiccation and consequent death of the leaf tissue. Elaborate studies have been conducted by State stations and by this department (*85*, *92*, *93*, *95*) on methods of curing and also on fermentation or sweating.

The early curing experiments at the Connecticut State station were concerned with water loss during curing (*17*), and the curing of Havana seed leaf tobacco by artificial heat (*9*), and analyses were made of tobacco stalks when cut and after curing (*12*). Curing studies at the Connecticut tobacco substation (*7*) gave indications that shade Cuban tobacco harvested slightly green will yield a higher percentage of top grades than tobacco picked very green or ripe to overripe. Aside from production of more desirable grades, the time during which tobacco can be picked and still yield very large quantities of top grades with control curing was at least three times as long as with barn curing.

Kentucky (*33*) experiments indicated that as high a grade of Burley leaf can be obtained by flue curing at a relatively low temperature as by air curing, thus eliminating completely the danger of house-burning. In experiments at the Kentucky station (*28*) where Burley tobacco was badly affected with houseburn, application of 10° of dry heat for an hour or more ended the trouble, and where heat was continually applied no house-burn developed. With the temperature from 100 to 120° F. tobacco cured with a greenish cast, but this was overcome somewhat by applying moisture at the same time.

The best results in Porto Rican (*68*) curing experiments were obtained in a large shed with a mean temperature of 77.7° F. and a relative humidity of 73.67 per cent. The slightly lower temperature and higher relative humidity in this shed apparently favored obtaining the best results. Leaf curing on wires cost more than the stalk cured at the North Carolina station (*47*) but the product was larger and of better quality, making the net receipts very much greater. The difference in chemical composition of like grades resulting from the two methods of curing was also reported on from this station (*48*).

A parallelism was apparent at the Pennsylvania station (*64*) between the humidity of the air in the curing shed and the catalase content of the Hibschman strain of Pennsylvania Broadleaf tobacco, but this response seemed to be governed largely by the fertilizer treatment and methods of curing used. The best cures in Wisconsin (*83*) experiments were usually obtained between 85 and 95° F., provided the humidity was kept high enough. If the temperature is too low or the humidity too low, the leaf usually cures out with a greenish color. When the temperature

is too high the leaf is killed quickly and develops an olive-green color. If, however, the humidity is too high, damage occurs owing partly to development of decay fungi in the tissues.

FERMENTATION

The details of extensive fermentation studies have been reported from the Connecticut State station (*11*, *17*). The upper leaves, short seconds, and first wrappers differed considerably in the proportions of water, dry matter, nicotine, and other constituents lost by fermentation. Short wrappers (*16*) decreased slightly in weight after fermentation but more than doubled in average fire-holding capacity. In experiments in cooperation with the United States Department of Agriculture (*90*) in fermenting Connecticut tobacco, the bulk method seemed superior to the case method of fermentation usual in Connecticut, greatly shortening the period of fermentation, tending to give a better color and aroma, and largely eliminating the element of chance. The fermentation process was considered remarkably successful in studies of barn curing and bulk fermentation (*20*).

Although the evening and setting of colors by both methods were satisfactory, the elasticity and water-retaining capacity and the taste of the bulk-fermented tobacco was far superior to control-fermented lots at the Connecticut tobacco substation (*7*). Much residual green coloring matter was present in the control-fermented but almost none in bulk-fermented tobacco, which had much more brown coloring matter. Control fermentation in the cabinet seemed to affect more the surface and not the body of the leaf to any great degree. The protein was not reduced more than half as much in the control-fermented as in the bulk-fermented tobacco. The chemical changes in the resweating of seed-leaf tobacco at the Pennsylvania station (*65*) closely resembled those of the first sweating process, of which the resweat seemed to be a continuation. Most of the nicotine lost is evidently lost by volatilization.

COMPOSITION

Numerous analyses have been made on the tobacco plant, its component parts, the leaf in various stages of growth, during curing and fermentation and on the manufactured product. Analyses of the tobacco plant at different stages of growth were reported from the Virginia station (*73*). Comparing high-grade and low-grade bright flue-cured grown in different Virginia (*74*) counties and in different years, the ash was about the same, and the lower grade contained about twice as much of each of nitrogen, phosphoric acid, potash, magnesia, and sulphuric acid as the high grade. The sodium and insoluble matter in the high grade was about six times as much as in the low grade, while the chlorine was about the same.

Results of extensive investigations in Ohio (*57*) showed that the composition of tobacco was modified more or less by different fertilizer treatments. Sodium nitrate application generally resulted in a decrease in total ash, phosphorus, sulphur, and chlorine, and increased the potassium content. Lime decreased the calcium and increased the magnesium in the tobacco complementarily. The most nitrogen was found in tobacco from unfertilized soil. Tobacco from plats receiving organic nitrogen has a higher nitrate nitrogen and nicotine content. Tobacco from plats treated with potassium contained more potassium than where none was applied, and tobacco from potassium sulphate or potassium nitrate plats contained more potassium than from potassium chloride plats. Tobacco from the manure-treated plat contained the most chlorine of any of the tobacco not fertilized with potassium chloride. Acid phosphate, used in combination with potassium chloride, tends to increase the chlorine content, and sodium nitrate to decrease it. Although potassium chloride used with acid phosphate and sodium nitrate excelled other potash forms in yield, this has been more than offset by the poor quality of the tobacco, as shown by smoking tests of cigars. Potassium in forms other than the chloride improved the quality of the tobacco. Sulphur present as sulphates in the tobacco exerted only slight influence on burning quality. Acid phosphate applied alone improved quality; in combination with potassium chloride any favorable effect appeared to be counteracted. Variations in flavor, aroma, and fire-holding capacity did not seem due entirely to the presence or absence of any one compound but are more or less dependent upon the total constituents of the tobacco.

Fertilizer results in Indiana (*26*) agreed in general with those reported above from the Ohio station. Plants variously fertilized with acid phosphate had a small petroleum ether extract and possessed the most agreeable aroma. Although the composition of tobacco may be greatly modified by fertilizer

treatment, the tobacco commanding the best price was grown on relatively poor sandy or clay soil, unsuited to corn, but producing a leaf characterized by a low percentage of extractives, proteins, and nicotine, and suitable for making a cigar of pleasing taste and aroma.

The good division of any grade usually contained a larger percentage of nicotine and generally more nitrogen and nitrate than the common in studies at the Kentucky station (*31*). Burley contained more nitrogen, nitrate nitrogen, phosphorus, potassium, and calcium than the dark tobacco and less nicotine, ash, silicon, and magnesium. The proportions of ash constituents, other than phosphorus and magnesium, differed considerably in the good and common grades. The good seemed to have the most potassium. Burley wrappers had the least silicon and calcium but the most potassium, the fillers the least ash and potassium, and the smokers the most ash, silicon, and calcium. Dark tobacco averages indicate that the leaf has the least ash and silicon but the most potassium and calcium, with the reverse holding in the trash.

NICOTINE

Considerable attention has been paid to the relation of the forms of nicotine and the organic acids of tobacco to the strength of tobacco intended for smoking purposes, with the aim of reducing the nicotine content or changing it by curing into forms more pleasing to smokers. The value of the nicotine for insecticide purposes has led to better extraction methods and also the breeding of tobaccos with higher nicotine contents.

According to observations at the North Carolina station (*49*) the nicotine at maturity is found mainly in the leaves, the percentage in the whole leaf in American grown tobaccos ranging from 1.96 to 5.53. Coarse rank growth is associated with a rather large nicotine content. The percentage of nicotine and albuminoids seemed to be materially increased by the extensive use of nitrogenous fertilizers. A large percentage of nitrogen in the form of albuminoids is usually accompanied by a high nicotine content. The percentage of nicotine in the leaf is largest just as the leaf reaches maturity, but the amount is materially reduced by the various fermentation processes before manufacture. Though nicotine is the active principle of tobacco and is desirable to a certain extent, the high-priced varieties examined contained relatively little. The nitric nitrogen appeared to be chiefly confined to the stems, and was not present in the leaf in appreciable quantities, except when the soil contained large quantities of nitrogenous fertilizers. The difference in chemical composition of like grades resulting from curing by the stalk process and by the leaf process on wire in North Carolina (*48*) was chiefly due to the manner and time of harvesting, being most noticeable in fillers, where the increased growth caused by priming the lower leaves in the leaf-curing process resulted in larger percentages of albuminoids and nicotine. Analyses at different growth stages showed that the nitrates were confined almost entirely to the stalk and stems in the younger growth of the plant, whereas the other nitrogenous substances were more abundant in the leaves.

Investigations at the Kentucky station (*31*) showed that the good division of any grade usually contains a larger percentage of nicotine than the common. Of the Burley grades, the fillers usually contain the most nitrogen and nicotine and the smokers the least. In dark tobacco the leaf usually has the most nitrogen, nicotine, and nitrate, and the trash the least. The Burley tobacco of both 1920 and 1921 contained more nitrogen and nitrate nitrogen but less nicotine than the dark tobacco. The differences in nicotine content at this station (*34*), especially in waste and very inferior tobacco, were such that the average percentage was not deemed a safe basis for the proportions of tobacco and water used in a spraying infusion. An improved method for the determination of nicotine in tobacco and tobacco extracts was developed at the Kentucky station (*35*).

Comparison of the Burley, Pryor, and Oronoco varieties at the Virginia station (*75*) showed very little difference in nicotine content in the plant taken from the plant bed; at the time of topping the agreement was very close as to the leaf, whereas in the stalk Burley contained about two and three times as much as Pryor and Oronoco, respectively. The difference is very slight in the root. At time of cutting the nicotine contents of the leaf were similar in Pryor and Oronoco, but Burley had over 0.5 per cent less than Oronoco and over 1 per cent less than Pryor. The percentages in the stalk at this time were similar in the three varieties. Among different grades of manufacturing tobacco light tobacco contained the least and the dark the most nicotine, which ranged from 1.54 per cent in high-grade bright flue-cured to 5.56 in English shipping. In

the dry matter of 11 varieties of tobacco grown at the California station (*2*) the nicotine content varied from 2.23 per cent in Vuelta Abajo to 9.03 per cent in Pano de Sumatra.

The total nicotine content in a sample of Connecticut wrapper-leaf tobacco (*89*) was 3.39 per cent before fermentation and 2.89 per cent after, while the nicotine soluble in petroleum ether amounted to 1.6 and 1.01 per cent, respectively. The undesirable sharpness or pungency of the smoke from certain types of cigar filler appeared to be due almost entirely to the volatile, easily soluble form of nicotine. On the other hand, the true physiological effects of the smoke seemed proportional to the total quantity of nicotine. The pungent, harsh quality of the smoke is partially removed by protracted resweating and aging of the tobacco, whereby the easily volatile nicotine is largely expelled.

NICOTIANA RUSTICA

The tobacco species known as *N. rustica* has been found to possess much more nicotine than the varieties of *N. tabacum* usually grown for manufacture into products for smoking and chewing. Analyses at Pennsylvania State College (*67*) of *N. rustica*, whose nicotine content had been increased by selection, disclosed that plants topped during growth contained 2.75 per cent of nicotine, suckered plants 3.79, plants topped and suckered 4.4, and untreated plants 1.61 per cent. In every case the percentage of nicotine in a topped or suckered plant greatly exceeded that of an untreated plant. Different kinds and quantities of nitrogen carriers seemed to affect profoundly the nicotine content of plants of *N. rustica* at the Pennsylvania station (*64*). Frosting appeared to increase the nicotine content and a further increase was noticeable after harvesting.

Considerable differences were observed at the New York State station (*44*) in the nicotine content of *N. rustica* from different sources and also among individual selections. The nicotine content was found higher in topped than in plants not topped. Broadcasted plantings were low in nicotine, whether highly fertilized with nitrogen or not. Dried blood and ammonium sulphate but not sodium nitrate seem to have increased nicotine to a small extent. Strains of the Pryor variety (*N. tabacum*) contained twice the amount of nicotine found in the previous year.

The investigations at this station (*45*) indicated that under identical conditions *N. rustica* develops a nicotine content about three times as large as do common strains of *N. tabacum*. Local environmental factors during growth seemed more potent than seed source in determining the nicotine content of a given variety of *N. tabacum*. Warm weather, favoring rapid growth and early maturity, evidently produced increased percentages of nicotine in the tobacco. The noticeable effect of soil treatments upon the nicotine content was slight compared with the seasonal or climatic influence.

BURNING QUALITY

Experiments on the burning quality of the leaf have been made by a number of the stations and by the United States Department of Agriculture. Tests with cigar tobacco by this department (*87*) indicated that for a good burn a heavy filler should be wrapped with a comparatively heavy wrapper and a light-bodied filler with a light-bodied wrapper, and that of the three components the filler exerts the strongest influence on the evenness of the burn. The wrapper and binder also strongly influence the character of the ash, and the binder very materially affects the ash of the wrapper. Other tests (*88*) were concerned with the relation of the composition of the leaf to the burning qualities of tobacco.

The fire-holding capacity of tobacco was increased by fermentation in Connecticut (*14*), although not equally in all cases. Tendency to "coal" when wrapped on a cigar was apparently not associated with deficiency in fire-holding capacity. Phosphoric acid seemed to influence combustibility only slightly in Maryland (*37*) but generally produced a marked yield increase. Potash salts seemed to be important factors in affecting the composition, forms containing considerable chlorine producing tobacco of poor quality and combustibility, whereas the sulphates and carbonates improved the quality and increased yield. In studies in North Carolina (*49*) burning quality depended more on the composition of the ash than upon the extent of fermentation. The best burning tobaccos were accompanied by a high percentage of ash constituents, particularly lime, and by potassium in proper combination. No connection was apparent between nicotine content and smoking quality in smoking tests of Ohio (*56*) filler tobacco.

GRAIN

"Grain," the small pimply projections found on the upper or outer surface of fully cured and sweated cigar tobacco of good quality, first appear a few days after curing has begun and the leaves have turned from yellow to brown. They are not found in fire-cured tobacco. They are composed of a mixture of salts, chiefly of lime and magnesia, with organic acids, largely citric and malic. Good burning Red Lion tobacco scored an average of 18 points for burn and 10.4 for grain at the Pennsylvania station (*63*), whereas poor burning tobacco scored 13 and 5, respectively, it appearing that grain development and burning quality are distinctly related. The good burning quality of leaf with well-developed grain is explained by assuming that the substances retarding the burn are gathered into the grain from surrounding tissue, which is left in condition to burn freely.

Grain was found not responsible for the marked hygroscopic properties of the tobacco in related studies by the United States Department of Agriculture (*98*). The small veins of the leaf showed the greatest hygroscopicity. In the tobacco studied the grain and burning properties were correlated. Other studies (*66*) related to those at the Pennsylvania station gave indications that the effect of salts in raising the temperature of the leaf may be significant, and that the action of caesium, potassium, and rubidium salts may be due to several complex factors. It seemed probable that these elements as carbonates, sulphates, and phosphates possess a specific catalytic action in combustion, and that the chlorides possess a negative catalytic action. The grain of wrapper was also investigated at the Connecticut State station (*19*).

REFERENCES

(1) Tobacco. A. J. Bondurant. Ala. Col. Sta. Bul. 54. 1894.
(2) Calif. Sta. Rpt. 1898, pp. 149–154.
(3) The growing of tobacco under shade in Connecticut. E. H. Jenkins. Conn. State Sta Bul. 137. 1902.
(4) A new and valuable cover crop for tobacco fields. A. D. Shamel. Conn. State Sta. Bul. 149. 1905.
(5) Tobacco breeding in Connecticut. H. K. Hayes, E. M. East, and E. G. Beinhart. Conn. State Sta. Bul. 176. 1913.
(6) Timothy as a cover crop for tobacco land. E. H. Jenkins. Conn. State Sta. Bul. 231. 1921.
(7) Experiments in the curing and fermentation of Connecticut shade tobacco, 1922. G. H. Chapman. Conn. State Sta., Tobacco Substa., Bul. 3. 1923.
(8) Fertilizer experiments with tobacco. N. T. Nelson, P. J. Anderson, et al. Conn. State Sta., Tobacco Substa., Bul. 5. 1925.
(9) Conn. State Sta. Rpt. 1891, pp. 187–196.
(10) Conn. State Sta. Rpt. 1892, pp. 1–28.
(11) Conn. State Sta. Rpt. 1892, pp. 28-31.
(12) Conn. State Sta. Rpt. 1892, pp. 31–34.
(13) Conn. State Sta. Rpt. 1893, pp. 112–144.
(14) Conn. State Sta. Rpt. 1894, pp. 254–284.
(15) Conn. State Sta. Rpt. 1896, pp. 310–333.
(16) Conn. State Sta. Rpt. 1897, pp. 243–256.
(17) Conn. State Sta. Rpt. 1898, pp. 297–307.
(18) Conn. State Sta. Rpt. 1899, pt. 3. pp. 252–261.
(19) Conn. State Sta. Rpt. 1899, pt. 3. pp. 262–264.
(20) Conn. State Sta. Rpt. 1899, pt. 3, pp. 286–297.
(21) Variation in tobacco. H. K. Hayes. Jour. Heredity, 5 (1914), No. 1, pp. 40–46.
(22) Ga. Coastal Plain Sta. Bul. 3 (Rpt. 1922), pp. 16–18. 1923.
(23) Ga. Coastal Plain Sta. Bul. 4 (Rpt. 1923), pp. 39–42. 1924.
(24) Ga. Coastal Plain Sta. Bul. 5 (Rpt. 1924), pp. 49–52. 1925.
(25) Guam Sta. Rpt. 1918, pp. 40–44.
(26) Chemical factors determining the quality of tobacco. V. Graham and R. H. Carr. Jour. Amer. Chem. Soc., 46 (1924), No. 3, pp. 695–702.
(27) Experiments with fertilizers on tobacco. M. A. Scovell. Ky. Sta. Bul. 28. 1890.
(28) Tobacco. W. H. Scherffius. Ky. Sta. Bul. 129. 1907.
(29) The relation of sulphur to soil fertility. O. M. Shedd. Ky. Sta. Bul. 188. 1914.
(30) I, Report on soil experiment fields.—II, Maintenance of fertility. G. Roberts and A. E. Ewan. Ky. Sta. Bul. 228. 1920.
(31) The relation of some chemical constituents to the grades of Kentucky tobacco. O. M. Shedd. Ky. Sta. Bul. 258. 1925.
(32) Ky. Sta. Rpt. 1918, pt. 1, pp. 22–24, 27, 28.
(33) Ky. Sta. Rpt. 1919, pt. 1, pp. 25–27.
(34) Ky. Sta. Rpt. 1922, pt. 1, pp. 20–25.
(35) An improved method for the determination of nicotin in tobacco and tobacco extracts. O. M. Shedd. Jour. Agr. Research [U. S.], 24 (1923), No. 11, pp. 961–970.
(36) Tobacco experiments in 1891, 1892, and 1893. H. J. Patterson. Md. Sta. Bul. 26. 1894.
(37) The culture and handling of tobacco in Maryland. H. J. Patterson. Md. Sta. Bul. 67. 1900.
(38) Experiments upon the use of potash as a fertilizer. H. J. Patterson. Md. Sta. Bul. 89. 1903.
(39) Fertilizer experiments with tobacco. W. W. Garner and D. E. Brown. Md. Sta. Bul. 225. 1919.
(40) On field experiments with tobacco in Massachusetts, 1893–1896. C. A. Goessmann. Mass. Hatch Sta. Bul. 47. 1897.
(41) Tobacco investigations. G. H. Chapman. Mass. Sta. Bul. 195, pp. 1–22, 31–38. 1920.
(41a) Havana seed tobacco as influenced by timothy cover crop. J. P. Jones. Mass. Sta. Circ. 73. 1925.
(42) Mass. Sta. Rpt. 1911, pt. 2, pp. 35–46.
(43) Effect of fertilizers on tobacco. G. C. Watson. N. Y. Cornell Sta. Bul. 49, pp. 320–322. 1892.
(44) N. Y. State Sta. Rpt. 1925, pp. 20, 21.
(45) Factors which influence the nicotine content of tobacco grown for use as an insecticide. R. W. Thatcher, L. R. Streeter, and R. C. Collison. Jour. Amer. Soc. Agron., 16 (1924), No. 7, pp. 459–466.
(46) Tobacco investigations at Baldwinsville, [N. Y]. R. C. Collison and J. D. Harlan. N. Y. State Sta. Tech. Bul. 94, pp. 12–36, 58–60. 1923.
(47) Tobacco-curing by the leaf cure on wire and the stalk processes. H. B. Battle, T. L. Blalock, and F. B. Carpenter. N. C. Sta. Bul. 86. 1892.
(48) Results of chemical analyses of tobacco cured by the leaf-cure on wire and the stalk processes. F. B. Carpenter. N. C. Sta. Bul. 90a. 1893.
(49) Types of tobacco and their analyses. F. B. Carpenter. N. C. Sta. Bul. 122. 1895.

(50) Harvesting tobacco by priming or picking the leaves as compared with cutting the stalks. E. G. Moss. N. C. Sta. Bul. 238. 1917.
(51) N. C. Sta. Rpt. 1918, pp. 34, 35
(52) N. C. Sta. Rpt. 1920, pp. 22–24.
(53) N. C. Sta. Rpt. 1921, pp. 24–29, 35–38.
(54) N. C. Sta. Rpt. 1923, pp. 26, 27, 43–46.
(55) Tobacco culture in Ohio. A. D. Selby and T. Houser. Ohio Sta. Bul. 238. 1912.
(56) Tobacco: Breeding cigar filler in Ohio. A. D. Selby and T. Houser. Ohio Sta. Bul. 239. 1912.
(57) Tobacco: Influence of fertilizers on composition and quality. J. W. Ames and G. E. Boltz. Ohio Sta. Bul. 285. 1915.
(58) Results of tobacco experiments in Pennsylvania 1912 to 1922. O. Olson. Pa. Sta. Bul. 179. 1923.
(59) Pa. Sta. Rpt. 1894, pp. 124–168, 357–363.
(60) Pa. Sta. Rpt. 1902, pp. 34–48.
(61) Pa. Sta. Rpt. 1910, pp. 238–243.
(62) Pa. Sta. Rpt. 1916, pp. 455–480.
(63) Pa. Sta. Rpt. 1916, pp. 481–485.
(64) Pa. Sta. Bul. 196 (Rpt. 1925), pp. 11, 12. 1925.
(65) Some chemical changes in the resweating of seed-leaf tobacco. H. R. Kraybill. Jour. Indus. and Engin. Chem., 8 (1916), No. 4, pp. 336–339.
(66) Effect of some alkali salts upon fire-holding capacity of tobacco. H. R. Kraybill. Bot Gaz., 64 (1917), No. 1, pp. 42–56.
(67) *Nicotiana rustica* as a source of nicotine for insect control. D. E. Haley, F. D. Gardner, and R. T. Whitney. Science, 60 (1924), No. 1555, pp. 365, 366.
(68) Tobacco investigations in Porto Rico during 1903–04. J. van Leenhoff, Jr. P. R. Sta. Bul. 5. 1904.
(69) The rational improvement of Highland Rims soils. C. A. Mooers. Tenn. Sta. Bul. 102. 1914.
(70) Dark tobacco fertility experiments at the Clarksville station—results from a ten-year period—1913–1922. C. A. Mooers and R. H. Milton. Tenn. Sta. Bul. 129. 1924.
(71) Willis and Huntsville tobacco soils. H. H. Harrington and P. S. Tilson. Tex. Sta. Bul. 61. 1901.
(72) Fertilizers on tobacco. Va. Sta. Bul. 12. 1892.
(73) Analyses of parts of tobacco plant at different stages of growth. R. J. Davidson. Va. Sta. Bul. 50. 1895.
(74) Analyses of different grades of manufacturing tobacco. R. J. Davidson. Va. Sta. Bul. 51. 1895.
(75) Percentage of nicotin in tobacco. R. J. Davidson. Va. Sta. Bul. 52. 1895.
(76) Virginia tobacco experiments. E. H. Mathewson, B. G. Anderson, and R. P. Cocke. Va. Sta. Bul. 175. 1908.
(77) Crop rotation and fertilizer experiments with sun-cured tobacco. W. W. Green. Va. Sta. Bul. 196. 1912.
(78) Experiments with dark tobacco. B. G. Anderson. Va. Sta. Bul. 206. 1914.
(79) Experiments with bright tobacco and other crops grown on bright tobacco farms. T. B. Hutcheson and D. J. Berger. Va. Sta. Bul. 233. 1923.
(80) Experiments with sun-cured tobacco and other crops grown in rotation with it. W. W. Green. Va. Sta. Bul. 242. 1925.
(81) Wis. Sta. Rpt. 1895, pp. 311–316.
(82) Wis. Sta. Rpt. 1906, pp. 201–208.
(83) Wis. Sta. Bul. 362 (Rpt. 1923), pp. 55, 56. 1924.
(84) An improved strain of Wisconsin tobacco: Connecticut Havana No. 38. J. Johnson. Jour. Heredity, 10 (1919), No. 6, pp. 281–288.
(85) Research studies on the curing of leaf tobacco. W. W. Garner, C. W. Bacon, and C. L. Foubert. U. S. Dept. Agr. Bul. 79. 1914.
(86) Tobacco diseases and their control. J. Johnson. U. S. Dept. Agr. Bul. 1256. 1924.
(87) Methods of testing the burning quality of cigar tobacco. W. W. Garner. U. S. Dept. Agr., Bur. Plant Indus. Bul. 100, pt. 4, pp. 31–40. 1907.
(88) The relation of the composition of the leaf to the burning qualities of tobacco. W. W. Garner. U. S. Dept. Agr., Bur. Plant Indus Bul. 105. 1907.
(89) The relation of nicotine to the burning quality of tobacco. W. W. Garner. U. S. Dept. Agr., Bur. Plant Indus. Bul. 141, pt. 1, pp. 5–16. 1909.
(90) Bulk fermentation of Connecticut tobacco. M. L. Floyd. U. S. Dept. Agr., Division of Soils Circ. 5. 1900.
(91) Field operations of the Bureau of Soils, 1901 (third report), M. Whitney et al. U. S. Dept. Agr., Field Operations of the Bureau of Soils, p. 32. 1901.
(92) Curing and fermentation of cigar-leaf tobacco. O. Loew. U. S. Dept. Agr., Rpt. 59. 1899.
(93) Temperature changes in fermenting piles of cigar-leaf tobacco. M. Whitney and T. H. Means. U. S. Dept. Agr., Rpt. 60. 1899.
(94) The work of the agricultural experiment stations on tobacco. J. I. Schulte and M. Whitney. U. S. Dept. Agr., Rpt. 63. 1900.
(95) Physiological studies on Connecticut leaf tobacco. O. Loew. U. S. Dept. Agr., Rpt. 65. 1900.
(96) History and status of tobacco culture. W. W. Garner, E. G. Moss, H. S. Yohe, F. B. Wilkinson, and O. C. Stine. U. S. Dept. Agr. Yearbook 1922, pp. 395–468.
(97) Breeding work with field crops at the experiment stations. H. M. Steece. U. S. Dept. Agr., Off. Expt. Stas., Work and Expend. Agr. Expt. Stas., 1924, pp. 43–59.
(98) Grain of the tobacco leaf. C. S. Ridgway. U. S. Dept. Agr., Jour. Agr. Research, 7 (1916), No. 6, pp. 269–288.

INVESTIGATIONS ON BACILLARY WHITE DIARRHEA INFECTION OF FOWLS

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Bacillary white diarrhea in the young chick is an acute, highly fatal, septicemic disease, manifested by a loss of appetite, sluggishness, drooping wings, and a pasty white discharge from the bowel, which adheres to the vent. It is caused by the *Bacterium pullorum* of Rettger (=*Salmonella pullora*). The causative organism occurs in the ovary of the carrier hen, from which it passes into the yolk and is transmitted through the egg. Weakened by the organism, the chick may succumb within the shell or during the early days of its life. Should the affected chick survive, it is usually stunted and may remain infected through life, to transmit the disease through its eggs. The hen, the ovary of which is thus affected, may yet succumb to the chronic form of the disease.

IMPORTANCE—MORTALITY

Bacillary white diarrhea was, during the first quarter of the twentieth century, by far the most important disease with which the poultryman had to deal. In the light of present knowledge, gained through research work to a large extent conducted at the agricultural experiment stations in this country, it should soon lose this standing, since the application of the blood test has made it possible to eliminate the infection from and to maintain clean, or accredited, flocks.

Loss may be caused by the disease in the following ways: (1) A marked reduction in fertility, (2) lowered vitality or death of chicks in the shell, (3) death of the young chick, (4) stunting of chicks that survive, (5) reduction in the number of eggs laid, and (6) even death of adult fowls from chronic and acute forms of the disease.

In a flock of 17 chicks observed by Rettger (*2*)[1] in Indiana, in 1899, over 82 per cent succumbed to the disease. Of the chicks in a flock studied in 1900 (*3*), 87.5 per cent died, while the disease killed about 80 per cent on two adjoining farms. Graham (*5*), of the Ontario Agricultural College, reported in 1904, losses of fully 75 per cent of brooder chicks within 5 to 10 days after hatching. Reference to poultry journals of about that period shows an extensive correspondence on the subject, losses of 50 to 75 per cent of entire hatches being not uncommon, and frequent appeals were made to the experiment stations to investigate the disease. Gifford (*8*) reported in 1905 that white diarrhea had cost him thousands of chicks in the preceding 14 years.

A mortality of practically 100 per cent was observed at the Connecticut Storrs station (*13, 26*) in 1906 in incubator-hatched chicks from eggs from different parts of the State. Graham (*17*), in Ontario, in 1908, reported a large loss of chicks between the fifth and tenth days, with a gradual dropping off up to 6 weeks of age. Some died quickly, others lingered for a week or more, and a few appeared to recover but remained small, unthrifty, and subject to roup and other infectious diseases. In an outbreak reported by Rettger and Harvey (*18*), then of Yale University, in 1908, almost 60 per cent of the 146 chicks exposed succumbed, the mortality being less than in the outbreaks observed in 1899 and 1900. Many farms that had never known the scourge before had suffered the loss of hundreds of chicks during the preceding two years.

That heavy mortality occurs among chicks before and also shortly after hatching was pointed out by Dryden (*20*), of the Oregon station, in 1908, and again by Pernot (*21*), of the same station, in 1908. In their first report from the Connecticut Storrs station, in 1909, Rettger and Stoneburn (*26*) concluded that the mortality depends upon the virulence and numbers of the organism, the mode and time of infection, and, doubtless, upon the vitality of the chicks. They described it as one of the worst things with which the commercial poultry raiser in New England must contend. Pearl, Surface, and Curtis (*33*), of the Maine station, stated in 1911 that, of all the diseases which the poultryman is called upon to fight, there is probably none so destructive, year after year, as white diarrhea, the loss varying in different years and places from 10 to 90 per cent. They estimated that 50 per cent of the chicks hatched throughout the country are lost from this form of white diarrhea. F. S. Jones (*34*), of the New York State Veterinary College, reported in 1911 that eggs artificially inoculated with *B. pullorum* did not give a high percentage of hatches. He recorded the loss by a

[1] Numbers in italics in parentheses refer to "References," p. 125.

commercial poultryman in New York of 90 per cent in incubator chicks and even more in hen-hatched chicks.

In further investigations, by Rettger and Stoneburn (*35*), in 1911, 100 day-old chicks given 4 to 6 drops of a 24-hour bouillon culture of *B. pullorum* showed a mortality of 71 per cent by the twenty-fifth day, whereas in the control lots only 4 per cent succumbed. The infected chicks which survived made less satisfactory growth. For some time they appeared stunted and weak, but eventually underwent more or less complete development. Trap-nest records indicated that infected hens were comparatively poor layers, this being especially true of hens in their second and subsequent laying years, such hens apparently laying regularly only in the spring and summer.

Kaupp (*74*), of the North Carolina station, stated in 1917 that the loss to poultry raisers from this disease was greater than from any other cause, perhaps greater than from all other infectious diseases combined. Losses of as high as 90 per cent of the station's hatch were recorded. In 1922 Kaupp (*98*) reported a death rate among young chicks of 75 per cent or more, the greatest loss occurring during the first few days up to, in some cases, two or three weeks.

Lewis (*90*), of the New Jersey stations, referred to it in 1921 as undoubtedly the greatest scourge of the poultryman. Beaudette, Bushnell, and Payne (*99*), then of the Kansas station, in 1923, reported a marked reduction in hatchability, 40 per cent of the several thousand fertile eggs recorded failing to hatch. They found that the adult carrier produced a much larger percentage of infertile eggs than does the normal hen (*105*). Newsom (*129*), of the Colorado station, reported in 1924 that, with the growth of larger hatcheries and the selling of day-old chicks, the disease had become very serious in that State, the mortality in many instances amounting to from 90 to 95 per cent of all day-old chicks received by certain poultrymen and farmers within the first week after their arrival, and many people hesitating to buy baby chicks under any circumstances. Roberts and Card (*155*), of the Illinois station, pointed out in 1925 that the losses may run as high as 80 or 90 per cent of the chicks.

Canfield (*148*), of the Michigan station, expressed the opinion, in 1925, that this disease probably was the cause of greater losses and more discouragement to poultry raisers and hatcherymen than any other poultry disease. He pointed out that by far the greatest loss caused by this disease is in the death of young chicks. Other losses occur through reduction in the hatchability of eggs, reduced egg production, and the increased susceptibility of infected hens to other diseases. In a comparative study of infected and noninfected birds in a flock, the egg production averaged 136, or 37.37 per cent, in infected and 166, or 45.46 per cent, in noninfected hens. The hatchability was 35.9 and 43.1 per cent, respectively, and the percentage of livable chicks 22.4 and 94.2 per cent. The age and number of hens observed was not stated. The trap-nest record of infected hens, reported by Doyle (*156*), of the British Ministry of Agriculture, in 1925, led him to conclude that the egg-laying power of the majority of carriers is very seriously impaired as a direct result of the disease.

Effect of B. pullorum in mammals.—In 1915 Smith and TenBroeck (*48*), of Harvard University, suggested that the closely related *B. sanguinarium* may be the cause of the occasional reports of gastrointestinal disturbances of man following the eating of the meat of infected fowls.

In April, 1916, Rettger, Hull, and Sturges (*58*) reported feeding experiments with rabbits, kittens, guinea pigs, and white rats, *B. pullorum* being introduced through the mouth and digestive tract. It was found that eggs which harbored *B. pullorum* in the yolk in large numbers produced abnormal conditions when fed, not only in young chicks and adult fowls, but also in young rabbits, guinea pigs, and kittens. The toxicity for young rabbits was most pronounced, the infection usually resulting in the death of the animals. In kittens the most prominent symptoms were those of severe food poisoning with members of the paratyphoid group of bacteria. It was pointed out that the possibility of infected eggs causing serious disturbances in young children and in the sick and convalescent of all ages must, therefore, receive serious consideration. These authors stated that Gage, in a personal communication, had reported finding rabbits very susceptible to even very small doses of *B. pullorum* subcutaneously injected, and for this reason it was very difficult to immunize rabbits to the organism. In 1916, Rettger (*60*) pointed out that since a large proportion of market eggs are infected with *B. pullorum* and soft boiling, coddling, and frying on one side do not necessarily destroy the *B. pullorum*, infected eggs may be the cause of serious disturbances

in susceptible persons, and especially in infants. He concluded that, although well authenticated instances of egg poisoning of this kind are lacking, it is not safe to assume that no cases have occurred, since the etiology of infantile stomach and intestinal disturbances is lacking, and the same is true of gastrointestinal disturbances of later life. Since the ailments caused by infected eggs would not be felt presumably until several days after their ingestion, little or no suspicion would fall upon the eggs.

Doyle (*156*), in 1925, reported guinea pigs to be susceptible, and rabbits very susceptible, to subcutaneous and intraperitoneal inoculation. Two rabbits that were given 3 drops of a broth culture in the eye died on the sixth and eighth day, respectively. A sheep inoculated subcutaneously with dead culture, then intraveneously with living organisms, developed no symptoms.

GEOGRAPHICAL DISTRIBUTION

Bacillary white diarrhea infection appears to occur throughout this country and in Canada, Japan, and Europe, and probably wherever poultry raising is practiced to any considerable extent. Doyle (*156*) states that it probably has existed in Great Britain for a very long time. It was recorded from Ontario in 1904 or earlier, by Graham (*5*). A writer in Farm Poultry in 1905 (*10*) recorded it as having occurred 20 years before, and other correspondents recorded it as occurring in Montana in 1905 (*7*) and in Utah in 1906 (*12*). It was first investigated in Indiana by Rettger in 1899 (*2*), since which time it has been studied by the experiment stations of many States, particularly those of Connecticut, Massachusetts, Maine, Rhode Island, New York (New York State Veterinary College), New Jersey, Maryland, North Carolina, Michigan, Indiana, Kansas, Louisiana, and Colorado, and Ontario, Canada.

In 1909, Rettger and Stoneburn (*26*) reported that extended inquiry had revealed the fact that the disease was prevalent throughout the greater part of the eastern section of the United States and in Canada. It was reported from Maryland by Gage (*37*), of the University of Maryland, in 1911, and as generally distributed throughout Massachusetts by Gage and Paige (*51*) of the Massachusetts station, in 1915. The disease was shown by Stafseth and Mallmann (*114*) in 1924 to have become widely distributed over the lower peninsula of Michigan. A study of its occurence in the United States was reported upon by Mulsow (*81*), of the University of Chicago, in August, 1919. From a study of publications and replies to letters written to all the State experiment stations, it was found that *B. pullorum* infection occurred in 18 States, in 12 of which, namely, California, Connecticut, Delaware, Illinois, Indiana, Massachusetts, Missouri, New Hampshire, New York, Oregon, Pennsylvania, and Rhode Island, it was of frequent occurrence, and in six, including Iowa, Kansas, Nebraska, Texas, Wisconsin, and Louisiana, it was of rare occurrence. No epidemics had been observed in 13 States reporting, and no studies made in 12 others. The occurrence of the closely related *B. sanguinarium* was recorded as frequent in 3 States (Connecticut, Massachusetts, and Rhode Island) and rare in 7 (California, Delaware, Iowa, Missouri, Pennsylvania, Washington, and Wyoming).

SUSCEPTIBILITY OF CHICKS

The domestic fowl appears to be the only animal susceptible to natural infection (*150*). From experiments reported in 1911, Jones (*34*) concluded that chicks are most susceptible to infection during the first 24 hours of life, are less susceptible after they have reached the age of 48 hours, and seem to be immune after the fourth day. In an experiment, six of fourteen 1-day-old and two of four 2-day-old chicks placed in contaminated quarters contracted the disease and died, and *B. pullorum* was isolated from each. Pure cultures were also obtained from four of the remaining chicks. After an extended trip among poultrymen who raise winter chicks, Rettger and Stoneburn (35) reported, in 1911, that a large majority had agreed that the chicks which are hatched in late fall, winter, or early spring are comparatively free from the disease. They concluded that infection from chick to chick does not take place after they are 3 or 4 days old. In 1912, Rettger, Kirkpatrick, and Stoneburn (*39*) pointed out that chicks which are 3 days old but of low vitality may more easily fall prey to the disease than 1-day-old chicks which possess much greater constitutional vigor. As a rule, however, the younger the chick the greater its liability to infection. They reported experiments in which four lots of 36 chicks each were infected when 36, 60, 84, and 108 hours old, respectively, with 4 or 5 drops of a broth culture of *B. pullorum*. It was found that the first 48 hours after hatching is the period of greatest danger of infection,

there being comparatively little danger to chicks of strong vitality after that time. Where the vitality was low, however, infection took place as late as the fourth or even the fifth days. It was seldom observed after the chicks had attained the age of 4 or 5 weeks, and there were few deaths as a direct result of the disease after the chicks had attained such age.

Canfield (*148*), of the Michigan station, found in 1925 that by far the greatest losses occur among young chicks from 4 to 16 days old. Chicks from 1 to 10 days old are principally affected, but deaths may occur up to the fourth week, according to Doyle (*156*)

SUSCEPTIBILITY AND INFECTION OF THE ADULT FOWL

Chronic form.—In 1909, Rettger and Stoneburn (*26*), reported that upon killing to market a large part of the old breeding stock at the Connecticut Storrs station in order to introduce new noninfected breeding stock, a large proportion of the fowls showed a pathological condition, particularly of the ovary. In experiments reported by Jones (*34*), in 1911, 2 cubic centimeters of a bouillon culture of *B. pullorum* injected into the breast and also into the wing vein of adults produced marked depression, which lasted for several days, but no other bad effects were observed, and the same results were obtained when larger quantities were injected, nor was any effect produced when large quantities of the culture were fed to adults. The organism was, however, found in the ovary and in the egg in the oviduct of 1 of the hens inoculated. Definite evidence of natural infection was first obtained by Rettger and Stoneburn (*35*), who reported, in 1911, that in every instance where hens known to be infected were killed and examined, the ovaries were abnormal in physical appearance and contained *B. pullorum.* They found that no matter how badly infected the ovary might be a large number of the ova were apparently normal. Little or no change of shape was observed in the small pathological ova, but they were more or less discolored and frequently showed slight changes in texture. The larger ova, however, often presented striking variations in shape and texture. They were frequently decidedly angular, and varied in their consistency from soft and liquid to firm and cheesy. There were various degrees of discoloration. In some instances the change in color was but slight, but frequently it was quite marked. At times some of the ova were found to be of peculiar bright yellow; again, they were quite dark, almost black, and occasionally more or less mottled. It was noted that the most virulent strain of the organism obtained up to that time was secured from an infected ovary. While found regularly in the abnormal ova, it appeared to be present in comparatively small numbers. In their examination of the ovaries of half-grown pullets, they found strong evidence in support of the theory that infected female chicks which survived the disease continued to carry the organism in their bodies, not in various organs, but locally in their ovaries, and became permanent carriers. It was at that time thought that, since noninfected hens kept in the same pen for months with infected hens did not become infected, the organism is not transmitted in that way.

Gage (*37*), at the Maryland station, reported in 1911 that he had found an inflammation and gangrene of the ovaries of a hen from which he isolated *B. pullorum.* Two hens and a pullet received for post-mortem examination were found to have suffered from ovarian infection. Thirty-two chicks given 2 drops of a bouillon culture of the organism by mouth and 30 others which were inoculated subcutaneously with a culture from 12 of the ova taken from the ovary of the pullet, all succumbed within 6 days.

Inoculation experiments with adults made by Jones (*38*), in 1912, indicated that intravenous injections of hens with pure cultures of *B. pullorum* may cause a local disease of the ovary. The eggs from these fowls failed to reveal the presence of the organism. Rettger, Kirkpatrick, and Stoneburn (*39*), reported, in 1912, that their later work had suggested the possibility that the infection might pass from adult to adult. In order to determine whether the infection is transmitted from hen to hen, 7 infected and 7 uninfected hens were kept together in an open-front house for 22 months. By testing the eggs it was found that 1 hen was infected in 8 months, a second in 16 months, and a third in 17 months. All 3 were killed and examined, and the organism isolated from diseased ovaries. A fourth hen, which had laid but few eggs, also proved to be infected with *B. pullorum.* In an experiment with mature stock, 48 early-hatched pullets were placed in pens in 6 houses in October, and a small amount of a broth culture of *B. pullorum* was sprinkled over the litter in three of the houses two or three times a week. Eight

of the 24 hens kept in these 3 litter-infected houses laid eggs which were found to be infected, 9 revealed infection of the ovary when they were killed, and a tenth was probably infected. None of the hens in the 3 check houses became infected.

Gage (*44*) reported, in 1914, that the lobulated and retention cysts, which varied greatly in size, were a striking pathological condition found in the ovaries. Rettger (*46*) considered it probable that the most active layers are the most susceptible to ovarian infection, since the physiological activity of the ovary is such as to lessen its vitality. Rettger, Hull, and Sturges (*58*) reported, in 1916, that they had obtained results much similar to those of Jones, but on a much smaller scale. Bouillon cultures of *B. pullorum* fed to fowls with the regular dry mash caused the death of 3 in a pen of 12 hens within a period of 1 to 2 weeks. *B. pullorum* was found in the organs of 2, but no marked or gross lesions were found. Other hens which appeared to be affected completely recovered in a relatively short time.

Doyle (*156*) reported, in 1925, that 1 of 4 fowls receiving 1 cubic centimeter of broth culture subcutaneously died on the fourteenth day, while the remaining 3 appeared unaffected. Tested 10 days after inoculation, the agglutination titer was 1 to 100, and at the end of 3 months all gave a negative reaction. Of 4 fowls which received 1 cubic centimeter of broth culture intravenously, 1 died on the third day, and 1 on the twentieth day. The 2 remaining reacted to the agglutination test for over 6 months. Of 4 fowls given 2 cubic centimenters of broth culture by mouth, 1 died on the eleventh day and the remaining 3 reacted to the agglutination test for 3 months. With two fowls infected by the injection of 1 cubic centimeter of broth culture into the oviduct, the agglutination titer on the tenth day was 1 to 50 and 1 to 25, respectively. One died from an intercurrent disease, and the other was killed 7 months later and the organism recovered from the ovary.

Acute form.—That *B. pullorum* may be the cause of an epidemic among grown fowls was first discovered by Jones (*40*), who reported in 1913 upon an outbreak in New York State. The owner of a poultry farm with about 700 hens had fed infertile incubator eggs to his hens, 50 of which died within 30 days. Pure cultures of *B. pullorum* were obtained from the pericardium, liver, spleen, and ovary. Jones decribed the disease as a true septicemia with a somewhat constant group of lesions, giving an account of the symptoms and postmortem findings at some length. The lesions usually found were minute necrotic foci in the liver, spleen, and pancreas and large necrotic foci in the heart muscle. The presence of a fibrous exudate on the capsule of the liver and spleen and on the pericardium and heart was quite constant. He found that the ovaries of fowls harboring *B. pullorum* are not always pathological. In 75 per cent of the spreaders the ovary was cystic, but in the remaining 25 per cent it was apparently normal. In this outbreak the first symptom noted was a paleness of the comb and visible mucous membrane, the comb appearing shrunken, scaly, and gray in color. The fowls appeared listless, and as the disease advanced depression became marked, the head drawn down, and the wings sagging. The appetite was lessened and diarrhea usually present, the tail feathers usually being soiled with yellowish-white feces. The disease ran a variable course, sometimes terminating fatally in 24 hours, but usually running a regular course of 4 or 5 days and sometimes even longer. The period of incubation was found to vary from 16 days to 3 weeks.

In 1917, Hadley, Caldwell, Elkins, and Lambert (*73*), of the Rhode Island station, reported upon the study of an epidemic among adult fowls in a Rhode Island flock, in which a mortality of about 10 per cent resulted. The organism insolated resembled the fowl typhoid bacillus but was finally identified as *B. pullorum*. They also made reference to two other outbreaks, one of which ran in a course absolutely parallel and caused the death of 4,000 out of a flock of 4,500 birds. The authors tentatively concluded that, as a general principle, when *B. pullorum* types assume a pathogenic rôle in adult stock, they tend to approximate the characteristics of *B. sanguinarium*, especially in the absence of the ability to form gas in dextrose or other sugars.

Gwatkin (*160*), of the Ontario Veterinary College, reported in 1925 upon two outbreaks in adult fowls in Ontario. In the first outbreak, 15 of a flock of 93 birds died, and a number of others were affected but recovered. In the second outbreak about half the flock was lost. *B. pullorum* was recovered from the ovaries of 55 of 60 hens which had reacted to the agglutination test.

Susceptibility of grown males.—It was thought by Rettger and Stoneburn (*35*), in 1911, to be quite improbable that adult males become infected, and examinations made on several occasions of

the testes of half-grown and adult males had given negative results. In feeding experiments with pure culture of *B. pullorum*, reported by Jones (*38*), in 1912, 6 of 40 chicks survived, 3 of which were males. The 3 males were reared, and, upon being examined as adults, were found free from infection. In agglutination tests reported by Rettger, Kirkpatrick, and Jones (*54*), in 1915, 2.9 per cent of 786 males gave positive reactions. The testes of 2 of the 11 males autopsied harbored *B. pullorum* in pure culture in large numbers, and in 4 of the males pericarditis and infection of the heart sac with *B. pullorum* was observed. All of the 157 males tested during 1915–16 (*63*), the second year (96 for first time), gave negative results. Of a total of 1,037 males tested, 2.1 per cent were found infected (*63*, *77*).

St. John-Brooks and Rhodes (*106*), of Lister Institute, London, in 1923, obtained a strain of *B. pullorum* from lesions in a cock which gave typical *B. pullorum* reactions with acid and gas formation in glucose and mannite and agglutinated in 1 to 6,400 with *B. pullorum* serum. Four out of 5 cockerels purchased by the Kansas station (*132*) from an eastern State reacted to the agglutination test, and reference is made to several others that reacted. Beaudette and Black (*172*), in their report of control work with the disease in New Jersey during the year 1924–25, recorded tests of 1,478 males, of which 55 reacted. They found that the infection in males is most often localized in the pericardial sac, occasionally elsewhere, and apparently but rarely in the testes.

ETIOLOGY—PATHOGENESIS

That a specific bacillus is the cause of the disease was first discovered by Rettger (*2*), then of the University of Indiana, in the course of studies made in Indiana in the summer of 1899. He succeeded in isolating the organism in that year from the liver, and in one case from the spleen of hen-hatched chicks affected with what was referred to as septicemia. Four chicks (2 to 4 weeks old) from unaffected broods that were inoculated subcutaneously with 0.5 to 1 cubic centimeter of a 24-hour bouillon culture developed the disease. Pure cultures of the bacillus were recovered from the liver of each of the 3 which succumbed, and in one instance from lungs and kidneys. It was also identified in the blood beneath the skin, and in two instances in the feces. In stained sections of the tissues, small slender bacilli were occasionally found, few in number and scattered through the sections. In 1901 (*3*), Rettger reported upon an epidemic occurring on three adjoining farms in Indiana, in which the same organism was proved to be the cause. He observed the disease in chicks 1 to 4 weeks of age, but chicks over 4 or 5 weeks of age did not appear to be affected. The inoculation of two chicks gave results similar to those in 1899. A detailed description was given of the organism, including its cultural characteristics and its resistance to antiseptics, followed by an account of its pathogenesis.

In 1904, Graham (*5*), at the Ontario Agricultural College, recorded the loss of fully 75 per cent of brooder chicks in 5 to 10 days, and pointed out that the disease had always been associated with chicks that had not absorbed the yolk properly. He had thought it might be an infectious disease, but a study made of it by a bacteriologist had given negative results. Gifford (*8*), in 1905, claimed the disease to be caused in the majority of cases by imperfect assimilation of the yolk, and V. A. Moore, as reported by Rettger and Harvey (*18*) in 1908, expressed the same view and considered the failure of the chicks to absorb the yolk to be brought about by a bacterial infection. In 1906, Graham (*13*), of the Connecticut Storrs station, reported upon the first occurrence of the disease in the station flock, which he concluded might be caused by a lack of vitality in the parent stock, musty food, faulty brooders, chills, overheating, or improper ventilation. It was pointed out by Ingalls (*14*), of New York, in 1907, that what is now known as bacillary white diarrhea is incurable, and different from the bowel trouble due to faulty feeding, uneven temperature in the brooder, poor ventilation, and filth. In 1908, Morse (*16*) reported investigations which led to the conclusion that white diarrhea is due to *Coccidium tenellum*.

A Pennsylvania incubator company was reported by Rettger and Harvey (*18*), in 1908, to have concluded that the disease was caused by bacteria, though they failed to produce the disease from the blood or diseased organs of dead chicks. In 1908, Rettger and Harvey (*18*) reported having produced the disease in five chicks, from 5 days to 4 weeks of age, by subcutaneous inoculations made during an epidemic. Two guinea pigs and a rabbit which they inoculated failed to contract the disease, although lesions appeared at the site of the inoculations and in one of the guinea pigs softened and became necrotic, the same cheesy contents having been observed as in some of the

chick lesions. In feeding experiments a 10-day-old chick fed a bouillon culture of the organism succumbed in four days, and the organism was obtained from the blood of the liver. An 8-day-old chick given bouillon cultures of the organism in its drinking water on two successive days developed the disease in nine days and died on the nineteenth day after the first feeding, the organism being recovered from the liver and the heart blood. They observed that the serum of a chick injected with dead and living cultures agglutinated the organism, as did the serum of an immunized rabbit. Its general morphological and cultural characteristics led them to place the organism in the colon-typhoid-hog-cholera group. They pointed out the importance of determining whether the egg becomes infected before it is laid or afterwards during the incubation period, or whether the bacillus enters the chick after it is hatched. They were inclined to the belief that incomplete absorption of the yolk is in no way responsible for the disease, but that it is a result of it, as they frequently found the absorption was apparently complete.

Milks (*19*) reported, in 1908, upon a very fatal infectious disease of young chicks under 5 or 6 weeks of age, investigated at the Louisiana station. He isolated from the liver and heart blood and described what is considered by Rettger (*24*) to have been undoubtedly the same organism. Two chicks into which 0.25 cubic centimeter of a 24-hour bouillon culture of the organism was inoculated subcutaneously died in 6 and 21 days, respectively, and the organism was recovered from both. Two other chicks to which a 24-hour culture was administered in milk failed to contract the disease, and no evidence of disease was discovered at a post-mortem examination 6 weeks later. One of three mice inoculated subcutaneously with 0.25 cubic centimeter of a 24-hour bouillon culture died 20 days later with septicemic lesions, and the organism was recovered from the liver. The other two showed no effect except abscess formation at the point of inoculation.

Pernot (*21*), of the Oregon station, in reporting on chick mortality in 1908 stated that he had constantly found a pathogenic organism present in the unabsorbed yolk of all chicks that had failed to hatch or had died shortly after hatching, and was led to the conclusion that birds died in the shell from toxemia. The same organism was isolated from chicks affected by a whitish diarrhea. In 1909, Hadley (*22*), of the Rhode Island station, reported investigations which had led to the conclusion that *Coccidium cuniculi* was the cause of the common form of white diarrhea in chicks. In a communication to Rettger (*24*), he reported having found *B. pullorum* in some of the chicks which had died.

In 1909, Rettger (*24*), in a paper that was read before the Society of American Bacteriologists in December, 1908, reported further, describing methods for the isolation and identification of the organism, and for the first time gave the name *Bacterium pullorum* to the causative organism. He also proposed the name "bacillary white diarrhea" to distinguish it from other forms of white diarrhea. It was found that the organism may be present in all of the internal organs of the chick, but particularly in the liver, spleen, lungs, and heart. The fact that the most careful search may reveal only a few scattered bacilli in one or two of the organs, while the remaining organs appear sterile, was pointed out. Even when the liver, spleen, heart, and lungs contained so few of the bacilli that the latter are found with some difficulty, they might easily be detected in the unabsorbed yolk. What was considered to be of importance also, was the frequent occurrence of the specific organism in the crop, stomach, and intestine. In a few cases *B. pullorum* was found practically pure and in large numbers, but as a rule the organism was mixed with other forms, especially *B. coli* and members of the *subtilis* group. Putrefaction rendered it difficult to find *B. pullorum*, as it was overrun by *B. coli* and other bacteria. It was very difficult to detect the bacilli in question in the dirt of the floors or grounds on which the chickens were running. Rettger also obtained additional evidence to show that chicks may acquire the disease through food and water that have been infected with the specific organism. It was suggested that chicks may be infected before they leave the shell, and that such infection may come originally from the hens which lay the eggs or during the period of incubation, the bacilli getting into the eggs through the walls of the shell. An examination was made of at least 60 eggs from various sources without finding *B pullorum* in the yolks of any examined.

In December, 1909, Rettger and Stoneburn (*26*) reported finding the organism in (1) the ova in the ovary of hens, (2) the yolk of fresh eggs, (3) eggs incubated for varying lengths of time, and (4) yolk sacs of fully developed chicks still within the shell, which they

considered as conclusive evidence that the hen was the original source of infection of the chick. They pointed out that the disease may be transmitted through an infected food supply. Thirty-four, or 68 per cent, of 50 chicks which received a few drops of water suspension of *B. pullorum* as taken from the incubator, and also added to their drinking water and used to dampen their food, succumbed. Of 180 other chicks to which *B. pullorum* was administered in a similar way, about 13 per cent succumbed. Of 396 chicks infected with bouillon culture of *B. pullorum* when 24 hours old and also given it in drinking water and on food, about 24 per cent succumbed as against 17 per cent in control lots. Eleven strong chicks were injected subcutaneously with a pure culture of the organism, and 100 per cent mortality resulted. A continuation of the search for the organism in the shell resulted in its detection in large numbers in the yolk of 1 of 12 fresh eggs. The yolks of 8 of 86 eggs which had been incubated for different periods of time were found to contain *B. pullorum* in large numbers.

Higgins (*28*), a Canadian pathologist, in 1909 considered the term white diarrhea to have been used to designate a number of widely separated affections. The form with which he was familiar was thought to be due, not to an infective agent, but "to a defective anatomical development prior to the emergence of the chick from the shell." The affected chicks which he had examined contained a partially absorbed yolk sac.

Jones (*34*) reported in February, 1911, that in six chicks examined in New York in April, 1910, a large unabsorbed yolk was found in each, the blood vessels surrounding the yolk being congested. *B. pullorum* was cultivated from their heart blood, liver, and unabsorbed yolk. It was shown to be pathogenic for young chicks when administered orally within the first 48 hours after hatching, and also to chicks 3 days old when injected subcutaneously, and to cause death in from 4 days to 3 weeks. Half-grown guinea pigs were found to be susceptible when injected subcutaneously, and to die in from 24 to 48 hours. The essential lesion was a large edematous area beneath the skin of the abdomen. The organisms were recovered in pure culture from all the internal organs. A rabbit weighing 1,660 grams, which was injected subcutaneously with 3 cubic centimeters of a 48-hour bouillon culture, died 7 days later. The most pronounced lesions were enlargement, softening, and congestion of the heart. The organism was recovered in pure culture from all the internal organs of inoculated chicks, guinea pigs, and rabbits. It was found that *B. pullorum* might be present in the egg, not only in the yolk of the embryo but in the white surrounding it and also on the inside membrane of the shell. The experiment indicated that the number of infected eggs was not great, but 1 of 69 eggs from infected flocks showing the presence of *B. pullorum*. It was shown that it is the yolk that first becomes infected. Eggs containing the organism appeared to be less likely to hatch, and this was further substantiated the following year (*38*). The conclusion was reached that infection does not take place from *B. pullorum* on the outside of the shell. That chicks are most susceptible to infection during the first 24 hours of life, the chances of infection decreasing as the chick becomes older, was indicated.

In April, 1911, Rettger (*36*) reported having found *B. pullorum* present in the ovary of a pullet, less than 8 months old, that was one of the survivors of an infected flock, thus showing the laying hen to be a carrier. The same month Rettger and Stoneburn (*35*), in their second report, in which they dealt at length with the source of infection, recorded finding the ovary of a number of hens to contain *B. pullorum*. They reported experiments in which large numbers of chicks were infected with three strains of *B pullorum* from infected ovaries, eggs, and chicks, the disease being produced at will. The organism was isolated regularly from the liver and unabsorbed yolks of chicks.

In June, 1911, Gage (*37*) reported upon investigations at the Maryland station, in which he found *B. pullorum* in large numbers in the diseased ovaries of a hen, and in each of 12 ova taken from a pullet with a diseased ovary. His studies fully substantiated the work of Rettger and Stoneburn, showing *B. pullorum* to be the cause of the disease and the hen to be the original source of infection, transmitting the organism from the ovary to the egg. He concluded that most of the white diarrhea of chicks in Maryland was due to *B. pullorum*.

In February, 1912, Jones (*38*) reported that 34 of 40 1-day-old chicks fed pure cultures of *B. pullorum* died of the disease. The 6 which survived (3 males and 3 females) with 6 purchased pullets from an infected flock were reared. When examined, 1 of the 3 reared females and 2 of the purchased pullets were found to have diseased ovaries, from which *B. pullorum* was isolated.

He reported upon an experiment which confirmed the finding of Rettger and Stoneburn that certain fowls overcoming the infection may become spreaders of the disease. He considered it clearly proved that *B. pullorum* may lodge in the ovary of the adult fowl. Since the disease in the young chick is a septicemia, and the organism is in the circulating blood, it is probably carried in this way and locates in the minute ovarian eggs, the egg yolk in the ova being a medium well suited to its development.

In a report published in December, Rettger, Kirkpatrick, and Stoneburn (*39*) dealt with further investigations of *B. pullorum*, the channels of infection, and means of prevention. In January, 1913, Jones (*40*) reported upon an outbreak of an acute disease in adult fowls due to *B. pullorum*. The same month (*41*) he first reported the successful application of the macroscopic agglutination test in detection of the organism in the adult fowl.

In April, 1914, Gage, Paige, and Hyland (*44*), of the Massachusetts station, confirmed the observation of Rettger, that the organism is more readily isolated from incubated eggs than from fresh eggs.

In a report published in June, 1914, Rettger, Kirkpatrick, and Jones (*45*) first showed that female chicks which are infected with *B. pullorum* when small, may in some instances retain a localized infection in the ovary, thus developing into permanent bacillus carriers and becoming a constant source of danger to young and old stock. They showed further that this carrier condition may be established in fully 25 per cent of an infected flock, thus connecting the cycle of infection. The same month Rettger (*46*) presented further data on ovarian infection and direct transmission to the offspring.

In 1915, Smith and TenBroeck (*49*) reported a comparative study of *B. pullorum* and *B. sanguinarium*, which led to the conclusion that the production of gas by *B. pullorum* and not by *B. sanguinarium* in dextrose and mannite bouillon or in dextrose only and the production of acid by *B. sanguinarium* and not by *B. pullorum* in maltose differentiates the two organisms (see p. 107). In 1916, Rettger, Hull, and Sturges (*58*) reported feeding experiments with *B. pullorum* and the toxicity of infected eggs (see p. 96). Taylor (*59*) concluded from his studies that, although there is a close resemblance in the biological characters of *B. sanguinarium* and *B. pullorum*, they produce distinctly different diseases. A study by Gage and Martin (*61*) of the pathological changes led them to conclude that the disease in small chicks is a septicemia, and that the minute necrotic foci in the liver, spleen, and pancreas are the most characteristic lesions.

In January, 1917, Rettger and Koser (*65*) reported a comparative study of *B. pullorum* and *B. sanguinarium*, their findings being similar to those of Smith and TenBroeck in 1915. In May, Goldberg (*69*) reported studies of the fermenting properties of *B. pullorum* and *B. sanguinarium*, his results indicating that they are distinct species, and corresponding with those of Smith and TenBroeck in 1915 and of Rettger and Koser in 1917. In July, Krumwiede and Kohn (*72*) reported on bacteriological studies of the *B. pullorum* group. In November, Hadley, Caldwell, Elkins, and Lambert (*73*) reported on a study of *B. pullorum* infection in adult fowls. In an outbreak among adult fowls, a strain of *B. pullorum* was found in eggs laid by some of the affected fowls, which, in some cases, failed to produce gas. Alpha and Beta types were designated. They emphasized the point that *B. pullorum* infections were not limited to young stock, they having observed three epidemics in adult stock. In the flock studied, the birds had been dying one or two at a time, many having suffered from diarrhea. Inoculation experiments with fowls and laboratory animals gave negative results. A postmortem examination revealed a typical picture of fowl typhoid infection, but in cultural studies the causative organism was found to possess the fermentation characteristics of *B. pullorum*. In experimental inoculations made with fowls, pigeons, rabbits, and mice the culture was found to possess very slight virulence.

In 1918, Hadley, Elkins, and Caldwell (*76*), in reporting on the colon typhoid intermediates as causative agents of disease in birds, dealt with the paratyphoid bacteria.

In January, 1919, Rettger, Kirkpatrick, and Card (*77*) recorded finding a large percentage of the hens, into the cloaca and oviduct of which *B. pullorum* was injected, to react to the agglutination test. Of these 25 per cent became permanent reactors. In April, Brown (*78*), of the Minnesota station, reported upon the relation of incubation to the occurrence of bacillary white diarrhea (see p. 104). The same month Scherago and Benson (*79*) reported experiments on the intradermal test for *B. pullorum* (see p. 117). In August, Mulsow (*81*)

reported upon a comparative study of *B. pullorum* and *B. sanguinarium*, his results being similar to those obtained by other investigators (see p. 109).

In 1921, Spray and Doyle (*84*), of the Indiana station, reported upon a study of the paratyphoids freshly isolated from chickens. They found 20 strains from chicks with lesions of bacillary white diarrhea and 2 strains from diseased ovaries of hens to be identical with a type strain of *B. pullorum.* In 1922, Gage (*93*), concluded that there are two forms of *B. pullorum*, confirming the findings of Hadley and his associates (73.)

In February, 1923, Beaudette, Bushnell, and Payne (*99*), of the Kansas station, reported upon a study of an organism from unabsorbed yolk of chicks dead in the shell, which they could not distinguish from *B. pullorum* by the fermentation reaction except by the inconstant reaction of the latter on maltose and xylose. Investigations reported by them in October, of the same year (*105*), showed it to be *B. pullorum*, and that the fowls had infected ovaries. A decrease of from 11.52 to 33.4 per cent in the fertilty of eggs was found in infected hens. In September, Hitchner (*104*) reported upon the macroscopic agglutination test as influenced by the fatty content of the blood serum (see p. 116). The organisms of the fowl typhoid group were studied by St. John-Brooks and Rhodes (*106*) in October. A bacteriological study of fowl typhoid and allied infections was reported by Edington (*130*) in 1924.

Mallmann (*151*), of the Michigan station, reported in October, 1925, upon studies of the cultural, physiological, and morphological characteristics, the agglutinability of 47 strains, and the keeping quality of antigen of *B. pullorum.* The resistance of chicks to the disease was reported upon by Roberts and Card (*155*), of the Illinois station, in December.

Doyle (156) also reported, in December that he had found 2.6 per cent of 341 eggs laid by 14 infected hens trap nested for 110 days to contain *B. pullorum.* It was found that only 4 of the 14 hens laid infected eggs, but their percentages were 3, 8, 14, and 18, respectively. Since the organism was recovered from the ovary of all the remaining hens, it was thought that the organism would eventually have been found in eggs laid by the other hens. The organism was never isolated from the egg white, which, however, has no inhibitory effect on *B. pullorm* growth. He concluded that the infected eggs were laid at very irregular intervals, and that the percentage, at least in some cases, may be much higher than it is generally supposed to be. In infection experiments, 3 of 6 chicks inoculated through the eye died on the fifth, sixth, and seventh days, respectively, and the organism was recovered from their internal organs. One of 4 grown fowls which received 1 cubic centimeter of a broth culture subcutaneously succumbed, as did 2 of 4 that received 2 cubic centimeters by mouth, and 1 of 2 that received 1 cubic centimeter by injection into the oviduct. Doyle isolated *B. pullorum* from 37 of 42 carrier fowls examined, it being found in the ovary of 88 per cent, the spleen of 26 per cent, gall-bladder wall of 21 per cent, kidneys of 9 per cent, liver of 4.7 per cent, and bile of 2.3. While it was found but once in the bile, the bile had no inhibitory effect on its growth. He concluded that the blood, bone marrow, and lung are not affected in the adult.

Gwatkin (*160*) reported in 1925 upon an outbreak in grown fowls in Ontario.

RELATION OF ARTIFICIAL INCUBATION TO THE DISEASE

That bacillary white diarrhea infection is more commonly met with in incubator-hatched than in hen-hatched chicks was the opinion expressed by many poultrymen in their early correspondence in poultry journals. W. R. Graham, of Ontario, as reported by Rettger and Harvey in 1908 (*18*, p. 279), pointed out that the disease is common in incubator and not in hen-hatched chicks. At the same time Rettger and Harvey stated that most investigators claim that the chief trouble lies in artificial incubation, as it is usually incubator-hatched chickens that are affected. Dryden (*20*), of the Oregon station, reported, in 1908, that 16.6 per cent of the chicks were dead in the shell when incubated artificially, while only 2.8 per cent of the chicks were dead in the shell when incubated under the hen. The belief of many poultry keepers that artificial incubation is the direct cause of the disease led to investigations by Brown (*78*), of the Minnesota substation at Crookston. Starting in 1912 with 600 Barred Plymouth Rock eggs laid by a flock affected with the disease, one-half were hatched artificially and one-half with hens. Eggs from the surviving pullets of the succeeding generations were hatched each year in a similar manner. Of the total number of chicks that died in the first generation, 66

per cent were affected with white diarrhea, including 2.7 per cent of the hen-hatched and 23.75 per cent of the incubator-hatched. The losses each year from white diarrhea in the incubator-hatched lots, starting with 23.75 per cent the first year, showed no indication of diminishing, and during the sixth year they increased to 69.48 per cent. The hen-hatched lots produced no white diarrhea chicks after the second year (1913). The percentage of loss from white diarrhea up to the age of 21 days for the seasons of 1913 to 1917 from eggs incubator hatched from the second to the sixth generations of the hen-hatched line was 25 per cent in 1913, 4 per cent in 1914, and none afterwards. The study led Brown to conclude (1) that white diarrhea can be controlled by the reversion to natural incubation, (2) that it disappears after the second generation of natural hatching, and (3) that it is not necessary to discard infected breeding stock in order to control the disease. No further work supporting this finding has been reported.

ISOLATION AND CULTURE

The organism causing this disease was first cultivated in 1899 by Rettger (*2*) on agar and bouillon from inoculations of blood of the liver and spleen. It stains with the ordinary aniline dyes but is Gram negative and does not produce spores. Rettger described the organism as a nonliquefying, nonchromogenic, aerobic, and facultative anaerobic bacillus. It is a long slender bacillus with slightly rounded ends. On agar plates small white colonies made their appearance in 24 hours at incubator temperature. On slant agar pronounced growth occurred in 24 hours. In agar-stick culture rapid growth occurred along the whole line of inoculation. On gelatin plates small white colonies made their appearance in 48 hours, and the gelatin was not liquefied. In gelatin-stick culture pronounced growth occurred in 48 hours along the whole line of inoculation. In bouillon abundant growth occurred in 24 hours at incubator temperature, and a similar growth took place in glycerin bouillon On potato development was very slow. Milk was not coagulated, nor indol, phenol, or cresol produced. In studies made during an outbreak reported upon in 1901 (*3*), the development on artificial media, and particularly on potato was more rapid than that of the first culture, due, it was thought, to the greater virulence and vigor of the organism.

98173—26†——8

In 1908 Milks (*19*) made cultures from the liver and heart blood of chicks and obtained what was undoubtedly *B. pullorum* from six and *B. coli* from four. Its growth on various culture media was described. He also found it to be aerobic and facultative anaerobic, to grow best at 37° C. and feebly at room temperature.

The Bacillus No. 9, isolated in 1908 by Pernot (*21*) from unabsorbed yolk and heart's blood of chicks that failed to hatch or that died in a few days after hatching, was probably this organism (*B. pullorum*).

The organism was cultivated by Rettger and Harvey (*18*) in 1908 and its characteristics again described. They pointed out that its morphological and cultural characteristics place it in the colon-typhoid-hog-cholera group. It closely resembles the *Bacillus cholerae-suis* in its ability to produce gas in dextrose and mannite media although *B. cholerae-suis* is actively motile and causes a strongly alkaline reaction in milk, whereas *B. pullorum* is nonmotile, or practically so, and never turns litmus milk blue. Its cultural characters were also described by Rettger (*24*) in February, 1909, and by Rettger and Stoneburn (*26*) in December, 1909.

In July, 1909, Rettger (*24*) first suggested that the infection of chicks may occur before they leave the shell, coming from the hens that laid the eggs, or entering the shell through the walls during the period of incubation. In the first examinations, however, he failed to detect its presence. In December, 1909, Rettger and Stoneburn (*26*) reported examinations of the shells of 12 fresh eggs from infected fowls, which gave negative results. The yolk in one case contained the bacterium pure and in large numbers. The yolks of 8 of 86 eggs (from 11 different varieties of fowls) which had been incubated for different periods of time were found to contain *B. pullorum* in large numbers and apparently pure. In an examination of the diseased ovaries of 20 hens, pure cultures of *B. pullorum* were obtained from 9. The finding of this organism in (1) the ova in the ovaries of the hens, (2) the yolk of fresh eggs, (3) eggs incubated for varying lengths of time, and (4) yolk sacs of fully developed chicks still within the shell was taken to be conclusive evidence that the hen is the original source of infection of the chick.

Jones (*34*) reported in 1911 that the organism may be present in the eggs, having been detected in 1 of 69 eggs examined. Gage (*37*), in June, 1911, reported that in investigations at the

Maryland station he had used the slant agar inoculation from tissues method of Rettger with success in cultivating the organism. In April, Rettger and Stoneburn (*35*) described an improved method devised for detecting the presence of *B. pullorum* in the eggs, by use of which a large amount of the egg is utilized. By the employment of this method the presence of *B. pullorum* in fresh eggs was readily determined. It was pointed out, however, that a large number of eggs must be examined before the investigator is justified in drawing the conclusion that the hens are free from infection. They found that in infected eggs, if kept at 103° F., the regular temperature of a commercial incubator, *B. pullorum* multiplies rapidly and is readily detected in a few days, even in small amounts of yolk.

The improved method of Rettger and Stoneburn was employed in 1912 by Jones (*38*), who found that some of the eggs laid by 2 of 9 hens known to be carriers of *B. pullorum* contained the organism. Of 34 eggs laid by 1 of these 2 hens, 14.8 per cent contained *B. pullorum*, as did 8.9 per cent of 41 eggs laid by the other hen. *B. pullorum* was found to be present in the whites as well as the yolks of eggs rejected during incubation. Rettger, Kirkpatrick, and Stoneburn (*39*) reported in December, 1912, that with chicks which had reached the age of 4 or 5 weeks *B. pullorum* had so far disappeared from the blood that it was usually impossible to find it there. Jones (*41*) pointed out, in 1913, that *B. pullorum* was easily recovered from the cystic ovary. In fowls that agglutinate but fail to reveal any marked pathological changes in the ovary, he recommended the ovary be removed with aseptic precautions to a sterile Petri dish, and there cut into several small pieces, and then crushed with a sterile spatula and dropped into tubes of sterile bouillon. The tubes should then be allowed to incubate 24 hours at 37.5° C., and from this suspension pure cultures may be obtained either by the plate method or by the inoculation of slant agar tubes.

MORPHOLOGY AND STAINING

The organism was described by Rettger (*2*), in 1900, as a bacillus with slightly rounded ends, which grown on agar, is 1 to 2 microns long, 0.3 to 0.5 micron broad, and usually occures singly. When grown in bouillon the size was found to vary considerably, being larger and longer, and often attaining a length of 3 or 4 microns, or growing out into chains of 2 or 3 bacilli. It does not produce spores. First described by Rettger in 1900 as actively motile, this finding was later corrected, and the organism was described in 1908 (*18*) as nonmotile. It was found to stain with the ordinary basic aniline dyes, fuchsine and soap solution of methylene blue being the most satisfactory. It proved to be Gram negative and not to retain its color when treated with very dilute nitric, hydrochloric, or acetic acid. Sections to be stained required 15 to 20 minutes staining in fuchsine or soap methylene blue and rapid dehydration. The maximum temperature for the bacillus was 56 to 57° C. (132 to 135° F.) for an exposure of 15 minutes, and the optimum temperatures 35 to 37° C. (95 to 99° F.).

In 1908 Milks (*19*), of the Louisiana station, described the organism as a small aerobic and facultative anaerobic rod with rounded end, 1.3 to 1.8 by 0.5 to 0.7 microns, nonmotile, but with Brownian movement, Gram negative, and nonspore forming. He found it usually to stain uniformly with the common dyes, though a polar stain was seen in some cases.

The organism isolated by Rettger (*2*, *3*) in Indiana in 1899 and 1900 was again obtained by Rettger and Harvey (*18*) in an outbreak in Connecticut in 1907, and its morphology and staining properties were again described by them, and also by Rettger and Stoneburn (*26*) in 1909. Jones (*34*), in 1911, described the organism as rod-shaped varying in size from 2 to 3.5 microns in length, with an average width of 0.5 micron. No capsules or spores were observed, and the bacilli were usually grouped singly or in pairs.

In a study of the morphological characteristics of 47 strains of *B. pullorum*, Mallmann (*151*), at the Michigan station, found no marked differences that would justify a separation of strains.

CLASSIFICATION—DIFFERENTIATION

The causative organism of this affection has been shown to belong to the intermediate, enteritidis or paratyphoid subgroup of the colon-typhoid group of bacteria, members of which subgroup are characterized by their ability to produce acid from rhamnose (*72*). Among other more important members of the subgroup are *B. enteritidis*, *B. cholerae-suis* (*suipestifer*), and *B. paratyphosus*. In the manual prepared by a committee of the Society of American Bacteriologists in 1923 (*110*), *B. pullorum* is placed in the genus Salmonella, species of which form gas from dextrose, and should be known as

S. pullora. The committee placed *B. sanguinarium* in the genus Eberthella, members of which do not form gas from dextrose, and accordingly it should be known as *E. sanguinaria*. *B. pullorum* is differentiated within the genus Salmonella, in that it forms acid and gas in mannitol, in dulcitol, and in levulose, but not in inositol or in maltose. *B. sanguinarium* is separated from other members of the genus Eberthella in that it forms acid in mannitol, in xylose, and in dulcitol, but not in lactose nor dextrin, and does not form indol.

B. sanguinarium (=*B. gallinarum* Klein, 1889), which is very closely related to *B. pullorum* and from which it must be differentiated, was first isolated in the United States by Smith (*48*), in 1894, during an epidemic among fowls in Rhode Island. It was first named and described by Moore (*1*) in 1895 from diseased fowls in the District of Columbia, Virginia, and Maryland, and the affection termed infectious leukemia. It was studied by Curtice (*4*) and Smith (*4, 48*) during an outbreak in Rhode Island in 1901, and the affection named fowl typhoid, by which name the disease is now commonly known. This close relationship has resulted in comparative investigations being conducted by a number of workers, particular attention being given to sugar fermentation tests because of the material difference in the action of the organisms on some sugar media. Such investigations were reported by Smith and TenBroeck in 1915 (*49*), Taylor in 1916 (*59*), Rettger and Koser in 1917 (*65*), Goldberg in 1917 (*69*), Krumwiede and Kohn in 1917 (*72*), Hadley in 1917 (*73*) and 1918 (*75*), Mulsow in 1919 (*81*), Spray and Doyle in 1921 (*84*), Gage in 1922 (*93*), St. John-Brooks and Rhodes in 1923 (*106*), Truche in 1923 (*101*), Edington in 1924 (*130*), Doyle in 1925 (*156*), and Mallmann in 1925 (*151*), who have found differences sufficient to regard the organisms as separate types.

Both organisms are Gram negative, and, as determined by the more accurate modern methods, neither form indol, although in the original account *B. sanguinarium* was recorded by Moore (*1*) as producing a small amount of indol.

Rettger and Harvey (*18*) reported in 1908 that *B. pullorum* produces both acid and gas in dextrose (20 per cent) and mannite (20 per cent) media. The gas consisted of carbon dioxide and hydrogen in the ratio of 1 to 3. In a furthur report issued in July of the following year, Rettger (*24*) stated that he had found different strains of *B. pullorum* to vary in their gas-producing power in dextrose bouillon. Some of the organisms isolated failed entirely to produce gas in dextrose medium. Two particular strains, however, fermented dextrose and produced 5 and 25 per cent gas, respectively. The more active of the two strains lost this property within seven or eight months and was for a while strictly anaerogenic, but the fermenting power was gradually being restored. Mannite was also fermented by some strains, but not by others. In 1909, Rettger and Stoneburn (*26*) and, again in 1914, Rettger, Kirkpatrick, and Jones (*45*) stated that some strains do not produce gas in any of the sugar media.

In 1911, Jones (*34*) recorded both the production and nonproduction of gas by *B. pullorum* on glucose and mannite bouillon. In a comparative study reported by Smith and TenBroeck (*49*), in 1915, it was found that recently isolated strains of *B. pullorum* produced a little gas in both dextrose and mannite bouillon or in dextrose only, but none was produced by the strain of *B. sanguinarium* used. A second difference was found in the action on maltose, which was acidified by *B. sanguinarium* and not by *B. pullorum*. In other respects the two appeared to be alike. The toxin production was found to be identical. It was concluded that the gas production of *B. pullorum* is of a fluctuating character, which seems to disappear during artificial cultivation. Smith and TenBroeck thought it possible that strains of *B. sanguinarium* when freshly isolated might produce gas. This latter point was apparently determined by Taylor (*59*), of the University of California, who conducted studies of an outbreak of fowl typhoid in that State in 1913, in which a freshly isolated strain of *B. sanguinarium* produced acid but no gas in dextrose in 72 hours. This was found by Goldberg (*69*) to be the same with year-old cultures. Agglutination tests made by Smith and TenBroeck (*49*) were found sufficiently definite to group the *B. sanguinarium* and *B. pullorum* types together. The close relation of the two was further shown by absorption tests.

In January, 1917, Rettger and Koser (*65*), reporting upon a comparative study of the two organisms, called attention to their close relation serologically. They found *B. pullorum* to produce gas (20 per cent) in dextrose and mannite media, while *B. sanguinarium*, whether recently isolated or artificially cultivated for many years, did not produce gas in any of the carbo-

hydrate media. A prolonged cultivation of *B. pullorum* did not cause it to lose its power to produce gas in dextrose and mannite broth. Dextrin, maltose, and dulcite were found to be attacked by *B. sanguinarium* with the production of acid but no gas, while *B. pullorum* produced no visible change in the media containing these agents except slight alkali production. The methyl red test applied to cultures grown in 1 per cent maltose bouillon was found to furnish a practical method of distinguishing between the two organisms, *B. sanguinarium* being methyl red positive and *B. pullorum* negative. Their findings were quite similar to those of Smith and TenBroeck in 1915.

In investigations reported in 1917, Goldberg (*69*) found four typical strains of *B. pullorum* to produce gas in various carbohydrates, including dextrose, mannite, galactose levulose, arabinose, and mannose, while *B. sanguinarium* lacked this power. His findings were similar to those of Smith and TenBroeck in 1915 and Rettger and Koser in 1917. In dulcite the four strains of *B. pullorum* produced slight acidity and gradually turned alkaline on prolonged incubation, while *B. sanguinarium* produced marked acidity. In dextrin results similar to those in dulcite were obtained, except that the acidity was not so marked. An atypical strain of *B. pullorum* was found which failed to produce gas in any of the carbohydrates, thus resembling the original Rettger strain. It was so markedly different from the other strain that Goldberg was in doubt as to whether it should be considered a strain of *B. pullorum.*

Krumwiede and Kohn (*72*) reported in 1917, that they had found gas formation by *B. pullorum* in glucose to separate it from *B. sanguinarium.* They found *B. sanguinarium* to form acid on maltose and dulcite, while *B. pullorum* did not. A culture, received from Smith and TenBroeck, of the strain of *B. pullorum* in which gas production was suppressed resumed its ability to produce gas from glucose, showing the tendency to variation in this characteristic.

Hadley (*73*), in 1917, reported that certain cultures isolated from infected eggs and also cultures isolated from adult fowls that died with a generalized infection failed to produce gas in dextrose broth. He pointed out that the *B. pullorum*-like strains that have the power to produce active and generalized infections in adult stock are differentiated from the strict type of *B. pullorum* as characterized by Rettger (*2*), in that (1) they do not form gas in any carbohydrate media, and (2) they manifest a low ability to ferment maltose, dextrin, and dulcite. This led him to suggest the recognition of a duality of type: (A) *B. pullorum* A, possessing the chief characteristics described by Rettger, a gas-forming type whose immune serum agglutinates *B. typhosus* about equally with its homologus antigen, pathogenic for young chickens only, and (B) *B. pullorum* B, resembling the type A in its chief characteristics but differing in that (1) it does not form gas in any carbohydrate, (2) its serum (like the antifowl typhoid serum) does not agglutinate, in high dilutions, human typhoid antigens, and (3) it is able to produce natural generalized infections in adult fowls, but only to a slight degree, if at all, in young stock. Hadley found that aerogenic strains, even after years of cultivation in artificial media, never lost their aerogenic powers, and no anaerogenic strain ever became aerogenic. Edington (*130*, *156*), on the other hand, stated in 1924 that every anaerogenic strain which he had studied in Great Britain became aerogenic on subculture. Hadley found that *B. pullorum* A manifests in maltose, dextrin, and dulcite an almost immediate lessening of the initial acidity; it is strictly maltose-dextrin-dulcite negative. *B. pullorum* B manifests a slightly delayed lessening of initial acidity, sometimes after a very slight increase (0.1 to 0.3 per cent); also a terminal alkalinity of a lower degree than in the case of the Alpha strains. *B. sanguinarium* gives an immediate increase of acidity, sometimes followed after some weeks by an alkalinity of low grade.

Studies reported by Hadley (*76*), in 1918, led to the recognition of six main disease types among the typhoid-like and cholera-like diseases of birds, which included (1) fowl cholera, due to *B. avisepticus*, of the Pasteurella group, (2) fowl typhoid, due to *B. sanguinarium*, of the actual paratyphoid group, (3) paracolon infections, due to paracolon bacteria in the strict sense, (4) bacterial white diarrhea, due to *B. pullorum* A, (5) infections in adult stock with *B. pullorum* B, and (6) infection with intermediate strains whose position is not wholly clear. *B. sanguinarium* is differentiated from the *B. pullorum* type in its ability to ferment maltose, dextrin, and dulcite; also from *B. pullorum* A by its failure to produce gas in any carbohydrate. *B. pullorum* is differentiated from *B. paratyphosus* B in being maltose-dextrin-dulcite negative. In respect to its reaction in litmus milk the *pullorum*

type is allied to paratyphoid A rather than to B. The *B. pullorum* A differs from *B. pullorum* B in that the latter shows a slightly greater tendency to form acid in several sugars and is anaerogenic.

Mulsow (*81*) reported, in 1919, an extensive comparative study of typical strains of *B. pullorum*, from which he was led to conclude that it can be distinguished from *B. sanguinarium* through its production of gas by most strains in several of the carbohydrates. Dulcite and maltose were, however, fermented by *B. sanguinarium* and not by *B. pullorum*, although a few strains of *B. pullorum* attacked maltose slightly. The strains of *B. sanguinarium* studied ferment rhamnose slowly, while the strains of *B. pullorum* ferment it promptly. He pointed out that *B. sanguinarium* does not, in general, take the ordinary stains as readily as *B. pullorum*, and often when stained with fuchsin the central portion is only faintly stained. His strains of *B. pullorum* did not grow, as a rule, as luxuriantly on agar and gelatine media as did *B. sanguinarium* or other members of the group. All but one strain of *B. pullorum* and two strains of *B. sanguinarium* produced a blackening of the medium along the lines of inoculation in 24 hours, due to hydrogen sulphide production. In agglutination tests with serum of rabbits immunized toward several strains of *B. pullorum* and *B. sanguinarium*, no agglutination difference was observed.

Spray and Doyle (*84*), of the Indiana station, reported in 1921 a study of 21 strains of paratyphoids from 21 outbreaks of highly destructive disease among chicks and 2 strains from the ovaries of mature hens, all but 1 of which strains were typical *B. pullorum*. All the strains produced gas from one or more sugars, with the exception of 1 strain isolated from a chick, which fermented the proper sugars but did not produce gas from any. No correlation could be shown in gas production from various sugars; some strains produced gas from glucose and not from mannite, while the behavior of others was exactly the reverse. Repeated tests were necessary to demonstrate gas production by some strains. All of the strains and the control strain of *B. pullorum*, usually regarded as unable to ferment maltose, produced acid and gas in 1 per cent maltose serum water. Maltose infusion broth was not fermented. The method employed by Spray and Doyle in their fermentation study was largely based on titration, at varying periods, of extract or infusion broth cultures containing 1 per cent of the desired carbohydrate. They found that the use of 1 per cent sugar serum water plus the Andrade indicator possesses certain advantages over titration, in that immediate and frequent observations may be made, gas production is readily detected, the slightest initial acidity may be noted, and reducing ability may be distinguished by the decolorization of the coagulated serum.

Investigations of 112 strains of *B. pullorum* were reported by Gage (*93*) in 1922. He found that *B. pullorum* was maltose-dextrin-dulcite negative and aerogenic, while all cultures of *B. sanguinarium* studied were also maltose-dextrin-dulcite negative but anaerogenic. These characteristics he found to be constant. It was found that whenever doubt arose as to cultural and morphological differentiations, the biochemical tests aided in making a final decision. From the examination of 600 avian specimens for the anaerogenic, nonmotile, maltose-dextrin-dulcite positive form, which produced large spleens, associated with marked leukemic conditions, the true *B. sanguinarium* was identified only six times. Chick examinations conducted during the same period, representing several hundred examinations, all yielded typical *B. pullorum* cultures, with the exception of one culture which was probably an atypical *B. pullorum* form that has become anaerogenic. Several times the anaerogenic form was isolated from dead hens, indicating the correctness of Hadley's contention (*73*), that *B. pullorum* may assume a dual rôle. The cultures from eggs were always found to be aerogenic. The differential characteristics of the cultures isolated from dead chicks which had been hatched from eggs laid by positive reacting hens proved to be typical *B. pullorum*. The several hundred agglutination tests made demonstrated an interagglutinability of *B. pullorum* with *B. sanguinarium*, *B. typhosus*, *B. paratyphosus* A, and *B. paratyphosus* B antigens.

In February, 1923, Beaudette, Bushnell, and Payne (*99*) reported upon the investigation of an organism isolated from the unabsorbed yolk of chicks dead in the shell. This strain differed from the typical *B. pullorum* in that it produced some acid on maltose, as was found by Mulsow in 1919. Injected into the eggs on the sixth day of incubation it proved pathogenic for the developing embryos. Truche (*100*), of the Pasteur Institute at Paris, reported in April that he had found *B. pullorum* always to produce gas in mannite,

arabinose, levulose, and glucose, and considered this characteristic the most important in differentiating it from *B. sanguinarium.*

In 1923, St. John-Brooks and Rhodes (*106*) reported fermentation tests and serological differentiation work with material acquired by the Lister Institute, London, from various sources during the preceding three years. They found *B. sanguinarium* to be indistinguishable from *B. pullorum* on serological grounds, but readily differentiated by its production of acidity in dulcite and maltose. They report that the distinction between *B. pullorum* A and *B. pullorum* B appears to be very artificial, both strains having been shown to affect either adult or young stock. The 36 strains isolated at Lister Institute from cases of white diarrhea were all nonlactose fermenters and produced acidity in glucose and mannite, but failed to ferment dulcite. Of these, 18 gave acid and gas in glucose in 24 hours, 6 more gave gas in 2 to 5 days, and 2 more on subculture from glucose peptone water cultures. The remaining 10 strains proved to be anaerogenic. All the 36 strains gave complete agglutination with a *B. pullorum* serum (titer 1 in 3,200) prepared from a *B. sanguinarium* strain at a dilution of 1 to 100. Most of their strains were obtained from lesions in chicks, but some were from adult fowls. The strain from *B. pullorum* lesions in a cock gave typical *B. pullorum* reactions with acid and gas formation in glucose and mannite, and agglutinated up to 1 to 6,400 with *B. pullorum* serum. Most of the strains which did not produce gas in glucose peptone water were derived from young chicks under three weeks old. The strain of *B. pullorum* B which they received from Rhode Island produced acid and gas in glucose and mannite when tested, although doubtless anaerogenic at the time of isolation. Thus they were led to conclude that the distinction between *B. pullorum* A and *B. pullorum* B, at least in so far as their relation to infectivity of stock is concerned, is of very doubtful value. They found that *B. sanguinarium* not only produced the lesions of fowl typhoid in adult birds, but also caused lesions in young chicks indistinguishable from those observed in *B. pullorum* infections, while *B. pullorum* produced in adult stock the symptoms of fowl typhoid. The lesions of bacillary white diarrhea were, moreover, consistent with those of a general septicemia with localized congestion and necrosis, the increased excretion of uric acid which gives the name "white diarrhea" to the disease being a common manifestation of generalized disorders in poultry. From these considerations it would appear that the two organisms are very closely related and may indeed be but varieties of the same species.

In 1924, Edington (*130*) reported that he had found agglutination and complement fixation tests to be of no value in the differentiation of *B. pullorum* and *B. sanguinarium.* Every anaerogenic strain of *B. pullorum* that he studied became aerogenic on subculture. Both types of *B. pullorum* were isolated by Konno (175) in Japan during the course of outbreaks in 1924.

In fermentation studies with 18 different carbohydrates, reported by Mallmann (*151*) from the Michigan station in 1925, only 2 of 47 strains of *B. pullorum* failed to produce gas in any of the sugars. These 2 he considered to be the anaerogenic strains described by Hadley as *B. pullorum* B. Only 3 of the strains produced gas consistently in all the fermentable sugars. The acid production in dextrose, mannite, galactose, levulose, mannose, and rhamnose broth was observed to be quite constant in occurrence, but on the other carbohydrates it was extremely variable. Biochemical tests showed variation in hydrogen sulphide and nitrites in Dunham's solution and nitrites in nitrate-peptone solution. These variations occurred among the strains and in the same strains at different times. No ammonia was produced by any of the strains in nitrate-peptone solution. In the first determinations with litmus milk all of the strains acted normally, but in the second and third series a number of them produced alkali after 14 days' incubation. The production of alkali was not constant for any 1 strain.

Doyle (*155*) reported, in 1925, tests of over 100 strains of *B. pullorum* isolated in Great Britian, the results being read on the tenth day. With maltose, lactose, saccharose, inulin, sorbite, and dextrin the results were negative, while glucose, mannite, and levulose tests gave acid and gas, or acid only. Strains isolated from chicks might be aerogenic or anaerogenic, the majority were aerogenic. He concluded that strains isolated from adult birds or from eggs may be aerogenic or anaerogenic, that the great majority are anaerogenic. The passage through young chicks of anerogenic strains isolated from adults frequently results in the recovered organism having acquired the power to produce gas. An aerogenic strain which had been passed through an adult fowl was, on recovery from the ovary five months later, found to be anaerogenic.

There was no difference in the virulency of aerogenic and anaerogenic strains for chicks, adult fowls, rabbits, or guinea pigs. He concludes that the gas producing powers of *B. pullorum* are of a fluctuating character, and that there does not appear to be any reasonable grounds for making two groups, as has been suggested by Hadley (*76*). A comparative test was made of the gas production of 24 strains of *B. pullorum* in peptone water media and beef extract media with glucose as the test substance. In the peptone water 13 strains were aerogenic and 11 anaerogenic. Four strains were constantly negative for gas, 2 of which were isolated from chicks and 2 from adult birds.

It is pointed out by Doyle that the majority of workers now appear to agree that aerogenic and anaerogenic strains of *B. pullorum* can be isolated from both chicks and adults, and that some strains lose the power of producing gas while others acquire it after cultivation on artificial media.

TENACITY OF THE ORGANISM

In his initial study of the organism, Rettger (*2*) found that when exposures were made in bouillon at incubator temperature the organism was killed in two hours by (1) 1 to 60,000 solution of corrosive sublimate, (2) 1 to 220 solution of carbolic acid, and (3) 2.5 per cent carbolic acid plus 1.5 per cent soft soap, 1 to 6. In 1908 Milks (*19*) found bouillon cultures to be resistant to boiling for 15 minutes. A 1 per cent carbolic acid prevented growth after 17 minutes but not after 15 minutes, and a 2 per cent solution prevented growth after 2½ minutes. The effect was tested by adding 5 drops of a 24-hour bouillon culture to 5 cubic centimeters of the disinfectant, the mixture shaken, and subcultures made in bouillon at intervals of 2½ to 17 minutes, being incubated at 37° C. for 5 days.

In 1908, Rettger and Harvey (*18*) showed that *B. pullorum* was killed by formalin, 1 to 700, when exposed in a bouillon culture for two hours at 37° C. A culture of the organism injected into chicks six months after it had been obtained from infected broods was found to have retained to a large extent its original virulence. In 1909, Rettger (*24*) reported finding that the organism is readily injured or destroyed by very small quantities of mineral acids and of lactic acid. It was found to be extremely sensitive to very small amounts of the lactic acid, bouillon tubes being rendered sterile when the acid was present for two hours in the ratio of 1 to 400, or 0.25 per cent. The resistance of *B. coli* was fully twice as great as that of the chick organism, it requiring 0.5 per cent lactic acid to kill all of the colon bacilli during the two hours' exposure.

Jones (*34*) showed, in 1911, that the organism is easily killed by disinfectants, being destroyed by 1 to 1,000 corrosive sublimate and by 5 per cent carbolic acid in 30 seconds, and by 1 per cent carbolic acid, 1 per cent creolin, and 3.33 per cent lactic acid, respectively, in 5 minutes. It was killed by boiling in 1 minute, but was not destroyed by heating to 60° C. for 30 minutes. In an experiment reported by Jones (*38*) in 1912, in which 40 1-day-old chicks were placed in a brooder that had housed infected chicks, no infection resulted, indicating that *B. pullorum* will not remain alive in a brooder over winter.

In 1916, Rettger, Hull, and Sturges (*58*) reported investigations of the survival of *B. pullorum* in the yolks of eggs after various methods of treatment with heat. Poaching the eggs for one-half to four minutes rendered them sterile. Scrambled artificially infected eggs were likewise found to contain no viable organisms. On the other hand, fried and coddled eggs gave varied results. Soft boiling, coddling, and frying on one side only do not necessarily render the yolks free from viable bacteria. In egg yolk boiling for four minutes did not in every instance kill the organism. This is thought to be due to the peculiar protection afforded first by the shell, then the egg white, and finally by the yolk itself.

ANATOMICAL CHANGES

Macroscopic — Chicks. — Post-mortem findings were first reported upon by Rettger (*2*) in 1900. He found diseased chicks to be very much emaciated, the crop empty, the intestines pale and almost empty, the liver pale with the exception of a few patches and streaks which were of a dark red color, and the spleen, lungs, and kidneys apparently normal. Morse (*16*) reported in February, 1908, that he had found only about one-half of the affected chicks examined to have unabsorbed yolks. In March, 1908, Graham (*17*) described post-mortem findings based on examination of 463 chicks. He found the lungs in about 50 per cent of the affected chicks to show white spots, particularly next the ribs, these spots being generally quite hard and cheesy. Some lungs (those in which chicks got chilled) were observed to have no white spots, but

to be red, sometimes fleshy in color. Some yolks were of a gelatinous nature or almost like the white of the eggs, others hard and cheesy and very yellow in color, and still others like curdled custard, with an offensive odor. The ceca were frequently filled with a cheesy substance. Of the 463 chicks examined, 44.7 per cent had cheesy spots in their lungs, 29.8 per cent had hardened yolks, and 28.4 per cent abnormal ceca. There were 22 per cent with abnormal lungs, yolk, and ceca, and 35.4 per cent with both lungs and yolk diseased. In August of that year Milks (*19*) reported that the post-mortem appearances were not marked, but as a rule quite uniform. The digestive tract was normal; the liver constantly enlarged, dark in color, and engorged in blood; the gall bladder usually filled with dark bile and the ureters with white or yellowish waters; lungs normal in all cases; and the heart filled with blood, its external blood vessels usually congested. In an epidemic reported by Rettger and Harvey (*18*), in May, 1908, the post-mortem appearances were essentially the same as in the epidemics observed in 1899 and 1900.

In a paper presented at a meeting of the Society of American Bacteriologists in December, 1908, Rettger (*24*) pointed out that the ceca may be practically empty or be partly filled with a semisolid or rather firm cheesy matter, and that the crop is empty or filled with either a slimy liquid or with food. In every case where the specific organism was obtained from the internal organs of the chick, there was found also more or less unabsorbed yolk, while in chicks of the same ages which died from other causes and in the control chicks the yolks were usually found to be completely absorbed. The yolk sacs of chicks affected with bacillary white diarrhea (septicemic) varied in size from a small pea to an Italian chestnut. Rettger and Stoneburn (*26*), in their first report of investigations at the Connecticut Storrs station, in 1909, gave a detailed description of post-mortem appearances. They stated that, unless the chick had been dead for some time, the yolk was usually not found to be putrid, but merely stale. The lungs were described as apparently normal.

In 1911, Jones (*34*) reported the unabsorbed yolk to be the most characteristic lesion of the disease. Its size was found to vary from being fully undigested down to the size of a pinhead. Its consistence was found to vary with the course of the disease, it being large and watery in the early cases and small and more gelatinous in those of longer standing. In the more chronic form it was hard and cheesy and somewhat difficult to cut. In a large number of cases the umbilicus did not seem to heal properly, and a partially healed opening remained which usually emitted a bad odor.

The post-mortem appearances were again described by Rettger and Stoneburn (*35*) in 1911 and in 1912 (*39*). Post-mortem examinations made of chicks dead from the disease, reported by Gage (*37*) in 1911, confirmed the findings of Rettger and Stoneburn. The yolks were unabsorbed in all but three cases. In an outbreak in Indiana reported in 1921, Spray and Doyle (*84*) found an enlargement of the liver, together with petechiae and necrotic foci in the liver and pneumonia and yellow friable nodules in the lungs, to be characteristic. Abscesses in the ceca were occasionally found. In 1924, Beaudette (*117*) reported the finding of a very noticeable yellow color of the liver, an unabsorbed yolk sac, and a bright red color of the lungs.

In 1925 Beaudette (*174*) reported the finding, in 1924, of small caseous nodules in the lungs of a large number of affected chicks. He pointed out that, while this lesion had been reported before, it seemed to have been overlooked by a number of investigators. In a large number of chicks affected with white diarrhea between the ages of 2 weeks and 3 months, he found peculiar lesions, consisting of nodules on the heart, which had not hitherto been described. In some of the cases only one large nodule was present, while in others a number of small nodules were observed. In most cases these nodules contained a white semifluid material, from which a pure culture of *B. pullorum* was isolated, and a similar culture was obtained in these cases from the heart's blood. In a very few instances these nodules were found on the serous surface of the breast bone, as well as on the gizzard

Microscopic—Chicks.—The microscopic appearances were first reported upon by Milks (*19*), in 1908, who found the liver to have the most pronounced lesions. In 1911, Jones (*34*) reported finding congestion in the lung and sometimes hemorrhage into the bronchiols. In the liver there was usually a marked congestion, cloudy swelling, and fatty degeneration, and often small foci of necrosis; in the kidney parenchymatous degeneration in the cortex and medulla, congestion in the capillaries between the tubules, fibrin

in the tubules; the spleen usually congested; and in the intestines there was usually a degeneration of the mucosa, but almost no congestion.

In a histopathological study of the intestines of young chicks, reported by Gage and Martin (*61*), in 1916, cultures from several sources produced typical bacillary white diarrhea, and death resulted from 3 to 10 days after the inoculation. Stained sections were made from various levels of the intestinal tract of the dead birds, a study of which revealed marked injury to the mucosa, associated with hyperemia, hemorrhagic exudation, and leucocytic infiltration. In the individuals in which the disease had run a longer course there were exhibited processes of regeneration. There was in many instances a thickening of the intestinal wall. There was a marked fibroblastic proliferation, and wherever any of the columnar epithelium was intact there was active secretion of mucus. It was concluded that with these pathological conditions associated, and with repeated observations confirming them, it is evident that the important histopathological conditions in the intestines in young chicks dead of *B. pullorum* infection correspond to either an acute or beginning chronic condition of catarrhal inflammation.

Macroscopic — Adults. — Rettger and Stoneburn (*35*) in reporting on chronic cases, in 1911, stated that no matter how badly infected the ovary might be many of the ova were apparently normal. Little or no change of shape was observed in the small pathological ova, but they were more or less discolored and frequently showed slight changes in texture. The larger infected ova, however, often presented striking variations in shape and texture. They were frequently decidedly angular, and varied in their consistency from soft and liquid to firm and cheesy. There were various degrees of discoloration. At times the ova were found to be of a peculiar bright yellow, while again they might be quite dark, almost black, and occasionally more or less mottled.

The post-mortem findings in acute cases were first described by Jones (*40*) in 1913, then by Hadley (*73*) in 1917, and by Gwatkin (*160*) in 1925. The heart was observed by Jones to be enlarged and congested in some cases, the muscles containing round grayish white nodules varying from 2 to 12 millimeters in diameter. The pericardial sac was surrounded with a mas of yellowish white gelatinous exudate. The liver was enlarged, softened, the surface sprinkled with minute grayish white areas of necrosis, with some fibrinous exudate present on the surface. The spleen was sprinkled with minute grayish white areas of necrosis. The surface of the pancreas had a number of tiny grayish white foci of necrosis. The kidneys were congested and very soft. The lungs were mostly normal. The ovary was congested, with irregular shaped retention cysts. In 75 per cent of the carriers the ovary was found to be cystic. In the intestines the duodenum was congested in some cases. Pure cultures of *B. pullorum* were obtained from the pericardium, liver, spleen, and ovary. The findings in a fowl examined at the Rhode Island station were described by Hadley (*73*). Gwatkin (*160*) found the lungs to have nodules and necrotic areas and some to show considerable inflammation, the findings being much the same as thoes of Jones.

Microscopic—Adults.—Tissue from fowls examined was sectioned by Jones (*40*), in 1913, including the heart, kidneys, liver, and pancreas. In the heart the principal lesion consisted in two comparatively large areas of coagulation necrosis. The muscle surrounding the nodules had undergone parenchymatous degeneration. Edema and an infiltration of leucocytes and fibrin was also noted between the muscle bundles. The blood vessels contained polymorphonuclear leucocytes in excess. The condition found is known as fibrinopurulent myocarditis. In the kidney there was marked acute hyperemia, the glomeruli showing some evidence of cloudy swelling. The tubular epithelium was in an advanced state of parenchymatous degeneration and in some parts of the specimen had become necrotic. A large number of the tubules contained varying amounts of fibrin. Fatty degeneration was also present. The condition is known as acute parenchymatous nephritis. In the liver the capsule was thickened with a fibrinous exudate containing a few leucocytes and fat droplets. The blood vessels of the capsules were congested. The liver cells in the center of the lobules were necrotic, but those around the edges were in an advanced state of parenchymatous degeneration. The capillaries contained large numbers of leucocytes and red blood corpuscles. A number of smaller veins were surrounded by dense masses of polymorphonuclear leucocytes. Congestion of the larger arteries and blood vessels was marked. Some hemorrhage into the tissue elements was present. In a more advanced case, the lesions were

about the same, although the necrotic areas were more marked and more numerous. This condition is known as acute parenchymatous hepatitis. In the pancreas the capsule, like that of the liver, was thickened with a fibrinous exudate containing leucocytes and fat droplets. In the earlier cases, the epithelium of the acini near the blood vessels were affected with cloudy swelling. In these areas the cell outline was obliterated, and the nucleus was pale. The blood vessels were hyperemic. In the cases of longer standing the centers of some of the lobules were necrotic. The intralobular connective tissue was infiltrated with fibrin. This condition is known as acute pancreatitis.

DIFFERENTIAL DIAGNOSIS

The objective symptoms are quite similar to those of coccidial and aspergillar or mycotic "white diarrhea," the presence of soft, whitish droppings and similar symptoms in each case causing them to be grouped under the common term white diarrhea, as pointed out by Jones (*34*), in 1911. Bacillary white diarrhea is distinguished from the other two by its early occurrence, the exceptional mortality, and the absence of the characteristic lesions of coccidiosis and aspergillosis, as pointed out by Ward and Gallagher (*83*), in 1920. Coccidiosis is slower in its development and usually affects chicks at a later period, and the coccidial cysts may be readily demonstrated by microscopic examination of the cecal contents. Aspergillosis, a mycotic disease, may be recognized by the characteristic fungal growth in the air passage and a microscopic study of it. The symptoms and lesions of fowl typhoid, due to *B. sanguinarium*, and acute *B. pullorum* infection of mature fowls are somewhat similar, and the organisms can only be differentiated by the biochemical cultural tests (see p. 107). Infection of the ovary by *B. pullorum* results in congestion and frequently the presence of hard irregular ova. Doyle (*156*) found a bacteriological examination to be the only reliable method of determining the presence of bacillary white diarrhea.

DIAGNOSTIC TESTS

Bacteriological.—The discovery by Rettger and Stoneburn (*26, 35*), in 1909, of the occurrence of *B. pullorum* in the yolks of eggs, followed by the finding of the organism in the ovaries of the hens that laid the eggs, led to bacteriological examinations being made of the egg and the ovary as a means of detecting infection in laying stock (*35*). They pointed out that the examination of incubator eggs is far more practical than the examination of fresh eggs. The common method of direct inoculation of the culture media, at first employed, was superseded by an improved method for testing fresh eggs, reported by Rettger and Stoneburn (*35*) in 1911.

In experiments reported in 1912, Jones (*38*) demonstrated that such a low percentage of the eggs laid by infected hens contain *B. pullorum* that egg examination is not a practical method for locating a spreader of the disease. As the result of an investigation of the value of the egg test for *B. pullorum* as a means of diagnosis, reported in 1914, Gage (*44*) was led to conclude that the elimination from the ovary is so irregular that the egg test is impractical for rapid diagnosis.

Direct examination.—Rettger, Kirkpatrick, and Stoneburn (*39*) pointed out, in 1912, that direct examination of the ovaries of mature hens is an important method of detecting infection in a flock. The bacteriological examination of eggs and ovaries was at that time, however, considered to be the most satisfactory method of detecting infection.

Agglutination test of chicks.—Agglutination experiments with chicks were reported by Rettger and Harvey (*18*) as early as 1908. In a test made of the blood of chicks which had contracted the disease naturally, a slight agglutination was obtained in a dilution of 1 to 50. The blood of a chick which had received several injections of dead and living cultures gave an agglutination in dilution of 1 to 80 in 1 hour 7 minutes; 1 to 60 in 45 minutes; 1 to 40 in 12 minutes; 1 to 30 in 7 minutes; and 1 to 20 in 4 minutes. The blood of a rabbit given three injections of dead (heated) bouillon cultures, followed by three doses of living culture at intervals of 4 and 5 days, gave an agglutination in dilution of 1 to 80 in 35 minutes; 1 to 60 in 30 minutes; 1 to 40 in 25 minutes; 1 to 20 in 20 minutes. It was concluded, however (*45*), that this was impracticable in detecting the disease in chicks.

Agglutination test of adults.—The application of macroscopic agglutination to the detection of infection in the mature fowl was first reported and described by Jones (*38*), in 1912, who perfected and demonstrated its practicability a year later (*41*). He described the

method by which the test fluid is prepared, it being made in practically the same way as that used in the diagnosis of glanders. *B. pullorum* was grown on slant agar tubes at 37.5° C. for two or three days, and the growth then washed off with 0.85 per cent sodium chloride solution containing 0.5 per cent of phenol. The organism was then killed by heating to 60° C. for one hour, or the fluid may be used without heating. The suspension was then passed through cotton to strain out the clumps of bacteria. The carbolized salt solution was then added to the filtrate until it became faintly cloudy. Three cubic centimeters of the test fluid was then poured into a narrow tube, and the diluted blood serum added by means of a finely graduated pipette until the desired dilution was reached, and thoroughly mixed. The tubes were then incubated three days. A positive reaction consists of a clearing of the fluid and a clumping of the bacteria on the bottom and sides of the tube. When the test was applied, five fowls that were spreaders of the disease gave positive agglutinations with a dilution of 1 to 200, and one agglutinated up to 1 to 500. The highest agglutination of a normal fowl was 1 to 50, and the majority failed to agglutinate at all. Five cubic centimeters of blood was sufficient to make a complete test. The lower serum dilutions (1 to 50, 1 to 100, 1 to 200) were recommended for practical purposes. Jones found that the blood serum of all the infected fowls agglutinated at a dilution of 1 to 100; the serum of 91 per cent agglutinated at a dilution of 1 to 200, and 82.3 per cent agglutinated at a dilution of 1 to 500. Certain individuals gave a positive reaction with serum dilutions of 1 to 800, 1 to 1,000, 1 to 1,500, and 1 to 2,000. The best results were obtained with a test fluid made from several freshly isolated strains of *B. pullorum*. A test resembling the tuberculin test was experimented with, but fowls injected with the concentrated bouillon filtrate of a culture of *B. pullorum* did not show a rise in temperature.

An extended study by Gage (*44*) of the macroscopic agglutination test recommended by Jones, reported in April, led to the conclusion that it is a good laboratory method of diagnosis. Agglutinins from infected hens were found which reacted positively in dilutions from 1 to 100 to 1 to 5,000. Test fluids preserved on ice were found to keep in a very active state for more than two months. Rabbits were ound to react to iniections with pure cultures of *B. pullorum*, and by very careful immunization yielded very active agglutinins, which were much more stable than from hens harboring the organism. Rettger, Kirkpatrick, and Stoneburn (*45*), in June, reported investigations of the macroscopic agglutination test as perfected by Jones, and described the method employed. They concluded that it furnished a reliable, inexpensive, and practical method of diagnosing ovarian infection in breeding stock. They pointed out that through its use a general campaign against the disease might be waged with every promise of success.

Gage and Paige (*51*), in 1915, reported in detail upon the application of the agglutination test to a number of breeding flocks. They urged the general adoption of this test as a means of eliminating the disease.

In 1916, Rettger, Kirkpatrick, and Jones (*63*) reported that a marked reduction on all but small flocks in the cost of the agglutination test was made possible by a simplification of the technique employed in the testing. Instead of making two transfers of the blood serum, as was done formerly, 0.03 cubic centimeter of the serum in the original blood tube was introduced directly into 3 cubic centimeters of the test fluid in which the final observations were made. A long series of tests with both methods showed that the results obtained with the shorter method were as exact and consistent as with the old. The modified method involved the use of 3 cubic centimeters of the test fluid (suspension of *B. pullorum* in carbonized physiological salt solution), but since the test fluid could be more readily prepared than when Witte's peptone was used in the culture medium on which the organism was grown, this should constitute very little of a drawback. On the other hand, much time and labor were spared in the actual testing technique and in the washing of test tubes. This work led Jones (*70*) to conclude that satisfactory tests can not be made until hens have passed one year of production.

Thompson and Dodson (*92*), of the New Jersey stations, in March, 1922, stated the discovery and development of the blood agglutination technique to be one of the greatest contributions to the science of poultry-disease control. By the application of the test to a breeding flock of 100 hens, 9 carriers were detected, the removal of which eliminated the chick loss. In investigations reported by Gage (*93*) in August, agglutination tests to the number of severa hundred demonstrated an interagglutin-

ability of *B. pullorum* with *B. sanguinarium*, *B. typhosus*, *B. paratyphosus* A, and *B. paratyphosus* B antigens. Since 924 infected hens were detected among 5,619 hens in 20 flocks, he concluded that, when carefully controlled through epidemiological work, it is the best method of locating *B. pullorum* infection.

The fact that blood sera of heavy laying hens gives unsatisfactory results in the agglutination test led Hitchner (*104*), of the Maine station, to conduct investigations in 1923, which showed that a period of starvation of at least 36 hours previous to bleeding reduced the high fat content of the sera and resulted in clear sera and excellent tests.

In 1923, Beaudette (*107*), then at the Kansas station, reported the finding of agglutinins for *B. pullorum* in the albumin of eggs laid by infected hens, all but 1 of 10 infected birds used in the investigation showing this characteristic. Agglutination was found to be most marked when a 1 to 8 dilution of egg albumin was used. In 1925 (*149*), he pointed out, however, that since all carriers do not produce eggs containing such agglutinins it can not be relied upon. He also described (*108*) a single-tube method for making the agglutination test which differs from the old routine method in that a drop of serum is used instead of a graduated amount. The drop of serum is placed in 4 cubic centimeters of highly diluted antigen, which gives a dilution of from 1 to 80 to 1 to 100. Because of its greater dilution, less than half as much antigen is required, and the time required for incubation is reduced by at least 24 hours. In 1924 Beaudette (*123*), at the New Jersey stations, recommended that, in order to avoid fatty material or cloudy serum, fowls be starved for 24 hours preceding the bleeding, and pointed out that it was desirable to test the fowls while they are in low production or even while in a molt. Investigations, conducted at the Michigan station by Stafseth (*165*), of the agglutination test with special reference to cloudy reaction, extending over three years, showed that the food consumed is not in any way related to the reaction. Males never showed cloudy reactions, and it is thought quite possible that the cloudy reactions may be due to metabolic changes associated with reproduction.

Blood agglutination tests at the Lister Institute, reported by Knight (*126*) in 1924, led to the conclusion that the disease can be controlled by removing birds that have reacted to the agglutination test from the breeding pens. In July, 1925, Brunett (*146*) gave a detailed description of the technique employed in making the agglutination test. It was pointed out by Beaudette (*149*), in September of the same year, that a positive agglutination test does not indicate infected ovaries in all cases, as the infection may be located elsewhere in the body, and also that young fowls may retain the agglutinin but not the infection, from having had the disease as chicks. Doyle (*156*), however, in December, basing his view on the results of bacteriological examination of a considerable number of reactors, stated that with this disease the agglutinin appears to indicate present infection, reacting birds always having an infection of the ovary.

In a study, reported in October, of the agglutinability of 47 strains of *B. pullorum* from Michigan, Mallmann (*151*) found some to be quite consistent in their relations to the sera studied, while others were extremely erratic. He considers it advisable, in using strains of *B. pullorum* for antigen, to select only those strains that show high titers toward all sera used, and that are consistent. He found that *B. pullorum* antigen prepared for the agglutination test can be kept generally about 12 months in a refrigerator at a temperature of approximately 10° C.

The agglutination test, resembling the Widal test for the diagnosis of typhoid fever in man and the tests applied for glanders in the horse and for bovine infectious abortion, is the method now generally employed in detecting infection in adult fowls. Beaudette (*149*), of the New Jersey stations, stated, in 1925, that it was generally accepted that a bird, the blood serum of which agglutinates the organism at a dilution of 1 to 100, is infected. The same year Doyle (*156*) stated that in Great Britain and in America agglutination in a dilution of 1 to 33 is considered to signify infection, and in Great Britain in a dilution of 1 to 50 or in lower dilution as doubtful. He stated that, as a result of recent work, he regarded complete agglutination in a dilution of 1 to 25 as a positive reaction.

Intradermal tests.—In 1917, Ward and Gallagher (*67*) reported upon an intradermal test for *B. pullorum* in infected fowls which they considered to show sufficient promise to warrant further extensive trials in the field in comparison with the agglutination test. They found a killed culture of *B. pullorum* grown for about a month and held for

several weeks before use and without further treatment other than carbolizing to give the most satisfactory results. The diagnostic fluid was injected into the dermis of the wattle, and an edematous swelling appeared in infected birds in from 24 to 48 hours. The ophthalmal, palpebral, and subcutaneous tests failed to produce a reaction. Experiments with the intradermal test, reported on by Scherago and Benson (*79*), of Cornell University, in 1919, led to the conclusion that it is so inconsistent as to be worthless as a diagnostic agent for *B. pullorum* in adult fowls. It was found that foreign protein introduced into the dermis might bring about a reaction which would vitiate the test.

Experiments reported by Fuller (*134*), of Cornell University, in 1923, led to the conclusion that, while the intradermal wattle test is much simpler and easier to perform than the agglutination test and detects a large percentage of infected individuals, it does not detect them all in heavily infected flocks. He pointed out that only a very small percentage of noncarriers react to the test. Brunett (*146*), of Cornell University, stated in 1925 that, while the intradermal wattle test had not been used very extensively, it appeared to have some merits.

SYMPTOMS

Chick.—The disease in the chick, as described by Rettger (*2*) in 1900, first showed itself by a loss of appetite and sluggishness; the feathers then became rough and diarrhea prevailed. Later the chick remained standing in one place and refused to eat, at which stage the wings were drooped and ruffled, and the chick became very poor, its neck and legs appearing unusually long and slender. As the disease progressed the chick became very sluggish and finally was unable to stand, and lay on one side with wings outstretched as if utterly exhausted. The throat and mouth seemed normal, and at no time did the chick show any signs of pain. He reported in 1901 (*3*) that in the first stages the chicks seemed to be feverish and more or less thirsty, and the progress of the disease was more rapid. Milks (*19*) reported in August, 1908, that the course of the disease was so rapid that many chicks died during the night without previously having shown any signs of illness. In others the symptoms described were similar to those reported by Rettger.

W. R. Graham (*17*), in March, 1908, described the symptoms as appearing on the fifth day, usually with a thin white discharge from the vent, though sometimes absent, inactivity and a sleepy appearance, with the head settling back toward the body. Some chicks search for the warmest spot under the hover, others have an intense thirst. Death took place in large numbers between the fifth and tenth days, continuing up to the end of the sixth week. A few chicks appeared to recover, but seldom, if ever, made good birds, remaining small and unthrifty. The symptoms in the epidemic and the induced infection observed by Rettger aud Harvey (*18*) in May, 1908, with the exception of the occurrence of lesions at the point of inoculation, a longer duration of illness, and in a few cases labored breathing, were the same as those observed by Rettger in the epidemics of 1899 and 1900 and experimental infections.

In July, 1909, Rettger (*24*) and, in December, Rettger and Stoneburn (*26*), pointed out that the symptoms may vary to a certain extent in different epidemics and in the individuals affected, due probably to a difference in the virulence of the bacilli or to the varied susceptibilities of the chicks. In each case, however, the rapid emaciation of the chicks and the whitish diarrheal discharges from the intestines were most prominent. Rettger and Stoneburn pointed out that the characteristic whitish discharge from the vent soon makes its appearance in the flock, the time depending upon the virulence of the organism and the mode of infection. The discharge may be slight or profuse, in color white or creamy, sometimes mixed with brown. The voided matter has a more or less sticky or glairy character, and the discharge may simply streak the down below the vent or may cling to the down in sufficient quantity to seal up the vent and bring about a condition known to poultrymen as "pasting up behind." The wings soon begin to droop or project slightly from the body, with the feathers ruffled. In acute cases the eyes are closed and the chicks become indifferent to what goes on about them. Many of the chicks peep or chirp constantly, the sound being shrill or weak, according to the strength of the individual, and frequently, when endeavoring to void excreta, the chicks utter a shrill twitter, apparently a cry of pain. The breathing may be labored, the abdomen heaving with each breath, and occasionally one may note a certain amount of gasping or gaping.

Jones (*34*) reported in February, 1911, upon symptoms observed in New York State, pointing out that in chronic

cases the legs appear to grow, but that the body does not, the apperance being referred to as "short backed." In ingestion experiments by Rettger and Stoneburn (*35*), in April, 1911, many of the day-old chicks which ingested 4 to 6 drops of a 24-hour bouillon culture of *B. pullorum* on the fourth day appeared listless, with a loss of appetite and a tendency to remain huddled in the brooders. At the end of one week the infected chicks had made no gain, while the others had increased fully 25 per cent. The infected chicks were stunted and never reached normal size. The symptoms were described by Rettger in 1914 (*46*) as those of acute bowel trouble, namely, diarrhea, listlessness, loss of appetite, subnormal temperature, and extreme weakness, especially in the later stages.

The period of incubation for the disease was said by Ward and Gallagher (*83*), in 1920, to be from 4 to 10 days. They include a lack of vitality, small stunted body, drooping wings, and a narrow, contracted appearance viewed from behind, as described by Lewis (*88*). The disease, according to Kaupp (*98*), is manifested by a frothy, white to whitish brown, pasty discharge from the bowel, which adheres to the vent fluff.

Adults.—The symptoms of the acute form in the adult, as observed by Jones (*40*) in 1912, were, first, a paleness of the comb and visible mucous membrane, the comb appearing to be shrunken, scaly, and gray in color. The fowls appeared listless, and as the disease advanced depression became marked, with the head down and the wings sagging. The appetite was lessened, and diarrhea was usually present, the tail feathers being soiled with yellowish white feces. Similar symptoms were observed by Gwatkin (*160*). Cases of adult infection with *B. pullorum* with symptoms similar to those of fowl typhoid were observed at the Kansas station (*132*).

COURSE

The disease is classified as an adult and chick infection, and appears in both acute and chronic forms, as described by Brunette (*146*) in 1925. In the chick it appears in the acute form as a result of infection in the egg or through contamination in the incubator or brooder in the early hours of life. It was observed by Milks (*19*) that the course of the acute form in the chick may be so rapid that many may die during the night without previously having shown any signs of illness. Canfield (*148*) pointed out that while the disease may prove fatal at any age, by far the greatest loss occurs among chicks from 4 to 16 days old. The chronic form in the chick is apparently due to a late infection from contaminated brooders or to an early infection with an organism of comparatively low virulence.

In the adult it is the chronic form, in which the infection is localized in the ovary, and the hen becomes a carrier transmitting the disease through the egg to the chick, that is commonly met with. The occurrence of the acute form as a septicemia in the adult fowl has been reported by several authors, including Jones (*40*) in New York State, Hadley (*73*) in Rhode Island, and Gwatkin (*160*) in Ontario. In origin this form may be endogenous, arising from an infection of the ovary, or exogenous, arising from the eating of eggs infected with the organism. In the adult the disease was observed by Jones (*40*), in 1912, to run a variable course, sometimes terminating fatally in 24 hours, but usually running a regular course of 4 or 5 days and sometimes even longer. The period of incubation varied from 16 days to 3 weeks. A variable course was also noted by Gwatkin (*160*), sometimes terminating fatally in 24 hours, but usually running a regular course of 4 or 5 days or longer.

NATURAL INFECTION AND TRANSMISSION

Experiments reported by Rettger and Harvey (*18*) in 1908, in which bouillon cultures of the organism were ingested by an 8-day-old and a 10-day-old chick, first demonstrated the possibility of infection when taken into the gastrointestinal tract. It was pointed out that this might serve to throw some light on the natural mode of infection, namely, from chick to chick through feces-contaminated food or drinking water.

The investigation of Rettger and Stoneburn (*26*), reported in 1909, led to the conclusion that the mother hen is the original source of infection of the chick. It was found that a certain percentage of the chicks on infected farms have the disease when hatched; further that the disease may be induced by subcutaneous injection of chicks with pure culture of the organism, and transmitted through infected food supply. In 1909, Rettger (*24*) stated that sufficient evidence was at hand to show that chicks may acquire the disease through food and water that have become infected.

In 1911, Jones (*34*) reported experiments from which he concluded that

the disease is transmitted in three ways: (1) Through the egg, (2) by direct contact in the incubator with individuals that have acquired the disease through egg infection, and (3) by day-old chicks being placed in contaminated surroundings. He pointed out that, while the probable number of eggs infected with *B. pullorum* is small, a chick hatched from an infected egg could infect a whole hatch. Rettger and Stoneburn (*35*) concluded, in April, that female chicks which survive often harbor the infection and may become bacillus carriers, infection in the breeding pen being perpetuated in this way. A diagram was given illustrating the manner in which the disease perpetuated itself in breeding stock. They reported that noninfected hens kept with infected hens apparently did not contract the disease.

The investigation reported by Jones (*38*) in 1912, showed that often, for comparatively long intervals, spreaders may not lay eggs containing the specific organism. Two newly hatched chicks were covered with a fluid containing *B. pullorum* and placed first in an incubator and then in a brooder with 36 that had just hatched, and during the following 4 weeks 11 of the chicks died of the disease. In 1914, Rettger, Kirkpatrick, and Stoneburn (*45*) reported further experiments showing that surviving chicks may become permanent carriers. A further account was given by Rettger (*46*), in 1914, of ovarian infection and direct transmission to the offspring.

Rettger, Kirkpatrick, and Card (*77*) pointed out, in 1919, that the spreading of infection from chick to chick apparently ceases after the age of 3 or 4 weeks. They found maturing and adult hens to be susceptible to infection from without, the rapidity with which such infection spreads varying with different flocks. In some instances the rates of spread within 12 to 15 months might be 20 or even 25 per cent of the entire flock. The results of experimental work, contrary to those of previous experiments (*39*), strongly indicated that transmission of infection from hen to hen through infected litter and by ordinary contact and association rarely, if ever, occurs, but indicated that the infection of pullets and fully mature hens may be brought about readily by infection of the cloaca and lower end of the oviduct. The conclusion was reached that males should not be allowed to run with the females except during the breeding season, because of the probable passive transmission from hen to hen. They concluded that testicular infection is too rare to play a significant part in the transmission of the disease from the male to the hens, and that the possibility of transmission of infection from hen to hen through the agency of the male as a passive carrier is of vastly greater importance. They considered circumstantial evidence of such transmission by the male to be so great that its transmission in this way could not be doubted. It was considered quite probable that *B. pullorum* is expelled from an infected ovary from time to time in appreciable numbers, and particularly when there is a rupture of one or more of the small infected ova, or during their reabsorption. The question of transmission of infection from the hen to the male was thought to require further investigation before a definite conclusion could be drawn.

Doyle (*156*) reported, in 1925, an experiment in which 50 naturally infected carrier adult fowls and 30 healthy controls were housed together in several pens for the period of one year, and none of the controls became infected, as was determined by monthly agglutination tests. It was pointed out by Canfield (*148*), in 1925, that affected chicks which survived seldom succeeded in freeing themselves from infection, remaining carriers as long as they lived.

PROGNOSIS

Chicks.—That a few chicks appear to recover, but seldom if ever make good birds, was the opinion expressed by Graham (*17*), in 1908. He had found chicks to remain small, unthrifty, and good subjects for roup or any other epidemic to which chickens are subject. In 1909, Rettger and Stoneburn (*26*) stated that a large percentage of infected chicks died under 4 weeks of age, and that those that survived the infection were weak and stunted and seemed particularly susceptible to other disorders. Beaudette and Black (*172*) state that about 25 per cent of the chicks which recover retain the infection, and that such infection may hinder growth for a few months, but after such period they show no physical signs of having had the disease.

Adults.—The possibility that a reacting hen which lays eggs the yolks of which contain *B. pullorum* may recover and no longer react is shown by the history of a hen reported by Horton (*64*), of the Missouri poultry station, in November, 1916. A bantam hen, in a flock of several hundred birds of which

65 per cent were infected, was found through the agglutination test, in December, 1914, to be infected, the infection being of ovarian origin, since pure cultures of *B. pullorum* were isolated from two unhatched eggs of a setting laid by this bantam in 1915. In the fall of 1915 the reaction was faint after 72 hours, and during 1916 two tests were made, both of which were negative even after 72 hours.

Doyle (*156*) found by means of monthly agglutination tests that of 14 carriers which had presumably acquired the disease in the chick stage 77 per cent were still infected at 2 years of age, and that 21 per cent of those which were infected up to the age of 12 months recovered during their second year. A bacteriological examination of the recovered fowls gave negative results. He concluded that the number which recover is too small to be of practical importance. Of 42 carriers examined, *B. pullorum* was isolated from 88 per cent, and pathological changes were found in the ovary of 69 per cent. While some writers state that a carrier may make a complete recovery in the course of two months and be safely used for breeding purposes, Doyle concluded, from the extensive pathological changes in the ovary of 29 of the 37 fowl, that it is unlikely that they ever make a complete recovery.

TREATMENT

The finding of *B. pullorum* in the crop in large numbers led Rettger (*24*), in 1909, to suggest that the feeding of well-soured milk at least two or three times a day would probably render the crop, stomach, and upper portion of the intestine sufficiently acid to hold the organism in check or even kill it. In an experiment conducted by Jones (*38*), in 1912, sulphocarbolates and creosote were fed in mash twice a day to 1-day-old and to 10-day-old chicks that were given 15 cubic centimeters of a 48-hour bouillon culture of *B. pullorum.* The results indicated that neither were of any great therapeutic value in the treatment of the disease. An extensive investigation of the value of sour milk in combating the disease was reported upon by Rettger, Kirkpatrick, and Stoneburn (*39*) in 1912—Hodge having previously recommended its use with quail and grouse. In all but two of seven experiments conducted its beneficial effect was demonstrated. In every instance the mortality was lower in broods which received sour milk than in the corresponding broods that did not. The milk was given to the chicks early in life and kept constantly before them. Bushnell and Maurer (*42*), of the Kansas station, reported in November, 1913, on feeding experiments with cultures of *Bacillus bulgaricus* which failed to show any superiority over ordinary sour milk. Their findings corroborated the more exhaustive studies of Rettger, Kirkpatrick, and Stoneburn. The sour milk had a beneficial action when given 40 hours before infection.

Jones (*43*) reported in 1913 that he had failed to obtain any beneficial results from the use of sulphocarbolates and creosote. In 1912 (*171*), 1914 (*163*), 1917 (*74*), and 1922 (*98*), Kaupp recommended the use of mercuric chloride at a dilution of 1 to 10,000 with sulphocarbolates of zinc, sodium, and calcium. Horton (*47*) reported work at the Oregon station in 1914 in which 50 chicks received the sulphocarbolate treatment, only 7 remaining alive at the end of 10 weeks. He concluded that, from the manner in which the chicks died off and from the appearance of the 7 that survived, the sulphocarbolates had very little if any efficiency. Rettger, Kirkpatrick, and Stoneburn (*45*), in an investigation of the carrier problem, reported in 1914, found the feeding of sour milk to infected chicks to reduce the percentage of bacillus carriers. Milk soured by *B. bulgaricus* was found to possess no distinct advantage over naturally soured milk. Rettger, Kirkpatrick, and Card (*50*) reported, in 1915, investigations which showed that, if fed soon enough and for a sufficiently long period, milk greatly reduces the death rate from bacillary white diarrhea. Sweet and sour milk appeared to be of equal value in their relation to growth and mortality. Jorgenson (*116*) reported briefly in 1924 upon a few tests which indicated that milk cultured with *B. acidophilus* prevented the disease in exposed field chicks and had a favorable effect on the course of the disease.

Beach and Freeborn (*94*), of the California station, pointed out, in 1922, that there is no satisfactory method of treating the disease, drugs being of no value for this purpose. In investigations of the influence of various dilutions of lactic acid, reported by Kaupp and Dearstyne (*150*), of the North Carolina station, in September, 1925, *B. pullorum* was found to have a limit of tolerance to lactic acid between 0.6 and 0.7 per cent. Canfield (*148*), in 1925, pointed out that there appears to be no therapeutic treatment that

has very much practical value. Beaudette (*117*) stated, in 1924, that treatment is of no value, should not be attempted, and that the chicks should be killed. Doyle (*156*) stated, in 1925, that attempts to cure affected chicks are futile and inadvisable, that, in spite of the many so-called cures on the market, there is no method of treatment yet discovered that is of the slightest value. The fact that many chicks which recover are potential sources of future outbreaks is a strong argument against the policy of treatment. Hinshaw (*153*) pointed out, in 1925, that, while the use of sour milk and medicinal agents may be of some value in prevention, curative measures should not be attempted in most cases.

PREVENTION

The perfection of the macroscopic agglutination test (see p.114) for detection of infected fowls by Jones (*41*), in 1913, has made it possible to eliminate the infection from a flock, and this is now recognized as the only satisfactory means of prevention. Many supplementary measures have been recommended.

In 1908, Rettger and Harvey (*18*) reported that through cleansing and disinfection of incubators and brooders, as well as inclosures in which the chicks are kept, are the best safeguards against the disease. The importance of increasing the resistance of the chick by preserving its vitality through proper feeding was also emphasized. In 1909, Rettger (*24*) referred to isolation of the birds, as well as disinfection of the incubators, brooders, poultry yards, etc., as preventive measures.

Jones (*34*), in 1911, presented experimental evidence to show that chicks may become infected by being placed in contaminated quarters, 12 of 18 chicks thus exposed having become infected, and at the end of three weeks the mortality was 44.5 per cent. The importance of disinfecting the brooders was demonstrated, since the disease did not develop in an infected pen that was completely cleaned and treated. The necessity for burning used litter; disinfecting houses, floors, and runways; and scalding feeding and drinking utensils was pointed out. Practical suggestions for prevention were made by Rettger and Stoneburn (*35*) in 1911, and in 1912, Rettger, Kirkpatrick, and Stoneburn (*39*) expressed the opinion that it should be both a moral and legal offense for persons to sell or exchange eggs, chicks, or mature stock which come from flocks that they know to be infected with the germ of bacillary white diarrhea.

Breeding for resistance is under way at the Illinois station (*155*, *159*).

IMMUNITY AND IMMUNIZATION

In investigations reported in 1915, Smith and TenBroeck (*49*) found that the bacterium-free filtrate of 5-day to 15-day-old bouillon cultures of *B. pullorum* were decidedly toxic to full-grown rabbits when given by intravenous injection. Death followed within two hours, or there was marked dyspnoea followed by death overnight or by loss of weight and subsequent recovery. The lesions induced included congestion of the liver, lungs, spleen, kidneys, adrenals, mesenteric lymph glands, and trachea, dilatation of the heart, and hemorrhage into the gastric mucosa. Immunization experiments with the disease were first conducted by Rettger and Harvey (*18*) in 1908. A chick which received subcutaneous injections at 8-day intervals of 0.25 and 1 cubic centimeter of bouillon cultures which had been heated at 60° C. for 10 minutes remained apparently normal. No noticeable protective action was established, as the chick died on the sixth day after injecting a live culture of the organism. A rabbit was given subcutaneous injections of 0.5, 1, and 1.5 cubic centimeters of bouillon cultures, which had been heated at 60° for 10 minutes, at intervals of six and eight days. No signs of discomfort or lesions developed, and after subsequent injection of living culture prominent lesions occured, but the rabbit remained normal in other respects. No definite conclusions could be drawn.

A bacterine made by Jones (38), in 1912, from a suspension of *B. pullorum* which had been killed by heating to a temperature of 60° C. for two and one-half hours did not produce any marked immunity in susceptible chicks. He considered it to have demonstrated that vaccines made from dead cultures of *B. pullorum* are not of any value in the prevention or treatment of the disease. Gage pointed out in a personal communication to Rettger, Hull, and Sturges (*58*)—reported in April, 1916—that rabbits are very susceptible to subcutaneous administration of even small doses of *B. pullorum*, and for this reason it is very difficult to immunize them to this organism.

Jorgenson (*116*) reported in February, 1924, that a serum from rabbits immunized with cultures of *B. pullorum*, when

fed twice a day in 5 cubic centimeter doses to chicks ill with bacillary white diarrhea and to well chicks exposed to the infection, apparently modifies the course of the disease and in healthy chicks serves to protect against it. It should be pointed out that this conclusion is based on a very limited number of tests.

Doyle (*156*) reported, in 1925, that the toxins produced by *B. pullorum* conferred no protection on rabbits, fowls, or chicks against artificial infection. He considered vaccines useless, as they confer no protection during the susceptible period, and the danger of acute infection has passed before immunity is acquired. Chicks that were given small doses of serum from a sheep hyperimmunized against three strains of *B. pullorum* contracted the disease in the same time as untreated controls. He stated that, although some workers may have reported favorably on the use of serum from hyperimmunized fowls, the inoculation of day-old chicks is not a practicable proposition, since they are far too delicate and fragile to permit of such intervention as a routine measure.

ELIMINATION—CONTROL

The investigations of the etiology of this disease have shown that control work must primarily be aimed at elimination of infected breeding stock. For detection of carrier fowls, the agglutination blood test perfected by Jones (*41*) in 1913 has been found most satisfactory and is now being quite generally employed. In reporting, in 1914, upon investigations of the agglutination test, Rettger, Kirkpatrick, and Jones (*45*) pointed out that, with the perfection of this test, a general campaign against the disease could be waged with every promise of success by applying it to breeding stock. They expressed the hope that Connecticut would be the first to conduct such a campaign. In 1915, Gage and Paige (*51*) reported investigations which led them to urge the organization of a campaign to eliminate the disease from breeding flocks in Massachusetts, in which the agglutination test would be adopted as the means of diagnosis.

Later, in 1915, Rettger, Kirkpatrick, and Jones (*54*, *55*) reported upon a campaign against the disease that had been inaugurated in Connecticut in June, 1914, in which efforts to eradicate the disease were based entirely upon the results of agglutination tests. During the first year of the campaign, 13,831 hens in 107 flocks were given the macroscopic agglutination test, of which 10.24 per cent were found infected, as were 2.9 per cent of the 786 males tested. The retesting of flocks which on the first examination by this method contained carriers and from which the reactors had been removed gave widely different results. In 4 flocks out of a total of 13, no reactors were found at the time of the second test, but in the other 9 the percentage of infection varied from 0.6 to 25.7, the number in each instance being decidedly less than in the first test. The breeding records obtained from the owners were most encouraging, and, with few exceptions, showed a large percentage of successful rearings as compared with previous years.

In 1916 Rettger, Kirkpatrick, and Jones (*63*, *70*) reported upon the second year of the campaign, in which 7,799 fowls were tested. Of the 6,262 fowls in 78 flocks tested for the first time, 8.2 per cent were infected and 1.4 per cent doubtful. All of the 1,441 fowls retested during the year gave negative reactions, though the flocks to which they belonged contained positive reactors. All of 157 males tested, including 61 retested males in infected flocks, gave negative reaction.

Control work was started in New Hampshire in 1918, when 4,000 samples were tested and 11,000 the following year, 10 cents per bird having been charged for making the test, the work being self-supporting. It was stated in 1921 (*85*) that, as a result of the tests, the loss of chicks from stock which had been tested was 29 per cent less than in previous years, when no testing was done. Many poultrymen reported losses as high as 60 per cent of all chicks hatched before the testing was done, whereas losses after testing ran as low as 5 to 8 per cent. Of 13,059 birds in 60 flocks tested in 1920, 60 per cent of the flocks and 7.66 per cent of the birds were found infected. Forty thousand birds were tested in 1922–23 (*112*).

In Massachusetts the work of inspection of breeding flocks to determine the presence of the disease, reported by Gage and his associates (*91*, *95*, *102*, *125*, *145*), was commenced in 1920–21, under a law enacted in 1919. From 24,718 fowls in 116 flocks tested in 1920–21, the number tested increased yearly until in 1924–25, when 66,503 in 156 poultry plants were tested. The percentage of reactors decreased from 12.5 in 1920–21 to 2.94 in 1924–25.

In an attempt to determine the prevalence of the disease in Kansas, the

station (*124*) tested 10 birds picked at random from each of 74 flocks in 13 counties located in different sections of the State. About 78 per cent of the flocks contained reactors, and 31 per cent of the birds examined were infected. Of 2,152 birds from 90 flocks in 25 counties, 38.3 per cent reacted. In work conducted by the Delaware station (*136*) in 1922–23, 9.2 per cent of 1,034 birds tested in 4 flocks reacted, and in 1923–24, 8.3 per cent of 1,868 birds in 9 flocks reacted.

Newsom (*129*), of the Colorado station, reported that of 1,394 fowls tested in 1924, 23 per cent reacted. Feldman (*157*), of the same station, reported a reaction of about 10 per cent of some 11,000 birds tested in that State during a period of 6 months in 1925.

Late in 1921, the Michigan station (*87*) announced that it was ready to make agglutination tests and examine diseased fowls for *B. pullorum*. In 1924 that station (*114*) published a map which showed the disease to be very prevalent in the more densely populated sections and to have become widely distributed over the lower peninsula. In the testing work conducted, 365 of 2,779 fowls examined in 1921–22 (*97*) were found infected, as were 1,792 of 5,059 fowls examined in 1922–23 (*109*), and 1,750 of 9,162 fowls examined in 1923–24 (*165*). Stafseth (*165*) of that station emphasized the importance in control work of constantly culling birds which show signs of disease. In support of this he refers to the case of a fowl that failed to react to a dilution of 1 to 50, in the abdomen of which an encapsuled abscess containing *B. pullorum* was found.

Merrill (*139*) reported that the disease was rather widespread in Maine, and was the cause of heavy losses to some poultrymen. During the year ended June 30, 1924, 13,145 samples of blood from 54 flocks were tested and less than 2 per cent found infected. It was pointed out by Canfield (*148*), of the Michigan station, in 1925, that, while the agglutination test to eliminate adult carriers is usually made some time before hatching season, once each year, until no reactors are found, some breeders get quicker results by testing twice each year, the first test being made during the fall or early winter and the second shortly before the hatching season. In Hancock County, Ind. (*162*), where some 10,000 hens in 30 flocks were tested in the spring of 1924, the percentage of reactors ranged from 2.3 to 57 per cent. A survey of 21 of these flocks showed that only 41 per cent of 16,109 chicks hatched were raised in 1923, whereas in 1924 64.6 per cent of 11,485 chicks were raised. The Illinois station announced in 1923 (*103*) that it was prepared to make agglutination tests. In 1925 it reported (*158*) that since October, 1923, the test had been applied to 363 flocks with 41,226 chickens, in 65 counties of the State. Of these about 13 per cent were infected, about 5 per cent were suspicious and probably infected, and about 80 per cent disease free. In some flocks the infection ran as high as 75 per cent, and only 2 of 363 flocks tested were found to be free. Of 50,480 birds from 391 flocks in 61 counties tested in 1924–25 (*166*), approximately 12 per cent reacted, only 5 flocks being found free from the disease. Clark (*144*), of Indiana, who in June, 1925, separated 3 flocks with a total of 617 birds and kept the reactors and healthy fowl under the same feeding and housing condition for periods of from 30 to 42 days, found the reactors to lay from 27 to 38 per cent fewer eggs than the uninfected fowl. Murray (*169*), of the Iowa station, reported that, of the 1,600 fowls in the Iowa College poultry flock tested in 1922, 30 per cent reacted and were removed. In 1923 but 3 per cent of the 2,000 tested reacted to the test, and in 1924 only five-twelfths of 1 per cent of the 1,200 birds tested were found infected.

In 1922, Gage and Flint (*95*, *102*, *125*, *145*) outlined three plans for testing, any one of which could be used by poultrymen cooperating with the Massachusetts station in eliminating the disease from their breeding flocks. The first two called for a retesting of the nonreactors in 6 to 12 months, while by the third the test was applied twice to pullets and to their offspring before being bred. According to Hinshaw (*153*), the Kansas station has used the latter plan with encouraging results. The need for universal adoption of a standard method of conducting the test was pointed out, in 1925, by Hinshaw (*153*), who reported that birds having a serum with an agglutination of 1 to 20 are classed as carriers by the station. He considered the elimination of adult carriers, combined with a sanitary program, to be the ideal means for control. A simple but effective system of management for control of the disease was described by Waite (*147*), of the Maryland station, in 1925.

In New Jersey the control work, as announced by Beaudette (*123*), who gave directions for the collection of blood samples, was commenced in 1924

as a part of the certification program of the State Department of Agriculture, in cooperation with the New Jersey stations. A description of the methods employed, including technique, and of the problems met with in New Jersey was given by Beaudette and Black (*172*), in reporting the results of control work in that State during 1924–25. Of the 28,103 birds tested during the year, 6.43 per cent were found infected. The infection in pullets was slightly greater than in hens, but cock birds were more heavily infected than cockerels. In general, the heavy breeds showed a greater infection than the light breeds except where only a small number of birds were tested. It should be pointed out that 20,206 of these fowls were handled under the State certified-accredited flock plan, and that but 2.76 per cent of the certified birds were found infected.

In tests reported by Doyle (*156*) in 1925, 21 of 84 chicks artificially infected gave positive reactions to the agglutination test 1 year later, all reactors giving evidence of ovarian infection. Of 21 2-months-old chicks which had survived an outbreak, 57 per cent were found infected. In tests made of more than 1,000 young birds on a farm where the disease had caused a heavy mortality during the previous breeding season, 40 per cent were found to be infected.

In agglutination test work, Beaudette and Black used a drop of blood serum to 4 cubic centimeters of test fluid, as employed in the single tube method (*108*), the resulting dilution being somewhere between 1 to 80 and 1 to 100 (see p. 116). It is pointed out that the question of what dilution should be considered diagnostic is still unsettled, some laboratories considering complete agglutination in a 1 to 10 dilution diagnostic, while others use a 1 to 50 dilution. As further pointed out, it depends a great deal upon the turbidity of the test fluid. If the test fluid is sufficiently turbid, it might be possible to use a 1 to 10 dilution of serum, while, on the other hand, if the test fluid is only of slight turbidity a correspondingly high dilution of serum must be used. The authors believe, however, that there is less opportunity for false reactions to take place when a test fluid of only slight turbidity is employed. They emphasized the fact that, since practically all reacting fowls agglutinate the organism in at least a 1 to 360 dilution, the dilution which they used is a safe one. Although it is true that occasionally a serum may be found that will cause agglutination in only 1 to 40 dilution, this does not necessarily mean that the fowl carries an active infection. Agglutination in this dilution might in some cases indicate the beginning of infection in the case of mature birds, but to eliminate such birds as carriers would likely throw out a large number of normal individuals, since about 75 per cent of the chicks which recover from the primary acute infection never retain it localized in the ovary. They consider it quite possible that the agglutination produced in low-serum dilutions is due to the persistence of agglutinins after the infection has failed to become localized. This reasoning, as pointed out, is based entirely on the serum-antigen dilution used in their laboratory. In their tests, where reaction occurred, in only four or five cases did agglutination fail to be completed.

Rettger (*166, 169*) is quoted as stating that the time has arrived when an intensive concerted effort to eliminate bacillary white diarrhea should be made through the various States in cooperation with the Federal Bureau of Animal Industry. It is his opinion that testing and control work should be placed under institutional auspices, preferably those of the Federal Government and experiment stations. The more specific replies to a questionnaire on control of the disease, conducted by the poultry office of the Animal Husbandry Division of the Bureau of Animal Industry, were assembled and issued on July 18, 1925 (*166, 169*). Station men contributing to the questionnaire include Rettger of Connecticut, Gage, Flint, and Bransfield of Massachusetts, Bushnell of Kansas, Stafseth of Michigan, Craig of Indiana, Runnells of Virginia, Murray of Iowa, May of Rhode Island, Goss of Ohio, Dimock of Kentucky, Beaudette of New Jersey, Lipp of South Dakota, Connaway of Missouri, Fitch of Minnesota, and Van Es of Nebraska.

ACCREDITATION

With the application of the agglutination test and the elimination of infection from the breeding flock, a demand has arisen for the accreditation of disease-free flocks by the State. Illinois is stated by Newsom (*129*), of the Colorado station, to have taken the lead in officially accrediting flocks, the State veterinarian issuing the accreditation and supervising the control. The licensed veterinarians draw the blood and leg band the birds, for which a fee of 5 cents per bird is allowed. The tests are made for an additional 5 cents, and the culling is done by the

veterinarian who drew the blood. After two negative annual tests the flock is accredited, the owner signing a contract to follow hygienic regulations set down by the State veterinarian (*173*). Newsom points out that in some States the accrediting is done under the direction of an association of poultry raisers.

Merrill (*139*) reported, in 1925, that 23 flocks containing 7,798 hens were placed upon the Maine accredited list for the year ended June 30, 1924. Beaudette and Black (*172*), in their report of control work in New Jersey in 1924–25, emphasized the fact that the term "accredited" is used in New Jersey to indicate a disease-free chick, whereas in some States the same term is used only to indicate a chick produced by a flock that has been culled for type and egg production but has not been tested for white diarrhea. It was stated in 1925 (*167*) that in approximately one-half of the States there is now in operation some form of accreditation or certification plan or both

A standardization conference was held at Manhattan, Kans., August 10–11, 1925, at which a uniform plan of accreditation and certification of poultry was adopted (*170*).

The work with *B. pullorum* as here reviewed would seem to support the conclusion of Beaudette (*149*), in 1925, that more is probably known about this disease than any other malady of the common fowl, and it would appear that a sound basis has been laid for practical control and even eradication.

In conclusion, the writer would call attention to the far-reaching effect that the investigations here related, conducted to a large extent by agricultural experiment stations, have had upon the poultry industry, the products of which, as pointed out by Director Shaw (*154*), of the Michigan station, are worth $300,000,000 more than the wheat crop, or more than a billion dollars annually. This accomplishment stands as one of the most striking illustrations of the economic benefits that have resulted from research work at the agricultural experiment stations of this country. It is not too much to say that when the accreditation work, now in its infancy, has become universally adopted and the disease practically eliminated from the American poultry yard, the saving as a result will far exceed the total amount now appropriated annually for research work at the experiment stations. Homage should be paid to the many investigators that have been engaged in and have contributed so unobtrusively to the solution of this great economic problem, and particularly to Rettger, F. S. Jones, Gage, and their associates, who led the way and have accomplished so much.

REFERENCES

(1) Moore, V. A.
1897. Infectious leukaemia in fowls, a bacterial disease frequently mistaken for fowl cholera. U. S. Dept. Agr., Bur. Anim. Indus. Rpt. 1895–1896, pp. 185–205.

(2) Rettger, L. F.
1900. Septicaemia among young chickens. N. Y. Med. Jour., 71, No. 4 (May), pp. 803–805.

(3) ———
1901. Septicaemia in young chickens. N. Y. Med. Jour., 73, No. 7 (Feb.), pp. 267, 268.

(4) Curtice, C.
1902. Fowl typhoid. R. I. Sta. Bul. 87 (Sept.), pp. 10.

(5) Graham, W. R.
1904. White diarrhoea in brooder chicks. Farm Poultry, 15, No. 11 (June), p. 252.

(6) Riley, F. H.
1904. Another opinion on white diarrhea. Farm Poultry, 15, No. 17 (Sept.), p. 358.

(7) Anon.
1905. White diarrhea in brooder chicks. Farm Poultry, 16, No. 9 (May), p. 256.

(8) Gifford, E. G.
1905. White diarrhea in incubator chicks. Farm Poultry, 16, No. 10 (May), p. 269.

(9) Foss, G. E.
1905. White diarrhea and natural methods. Farm Poultry, 16, No. 12 (June), p. 307.

(10) Buffinton, R. G.
1905. Not the first diarrhea epidemic. Farm Poultry, 16, No. 14 (July), p. 345.

(11) Wallis, W. T.
1905. The diarrhea question. Farm Poultry, 16, No. 15 (Aug.), p. 359.

(12) W. D. R.
1906. White diarrhea in chicks. Farm Poultry, 17, No. 10 (May), p. 279.

(13) Graham, C. K.
1906. Poultry observations.—I, Causes of death of young chicks. Conn. Storrs Sta. Bul. 44 (Nov.), pp. 25–28.

(14) Ingalls, H. R.
1907. A "white diarrhea" theory. Farm Poultry, 18, No. 11 (June), p. 279.

(15) Anon.
1907. [White diarrhea]. Ontario Poultry Inst. Ann. Rpt., 2, 1906–7, pp. 36, 52, 54, 58, 65.

(16) Morse, G. B.
1908. White diarrhea of chicks, with notes on coccidiosis in birds. U. S. Dept. Agr., Bur. Anim. Indus. Circ. 128 (Feb.), pp. 7.

(17) Graham W. R.
1908. General symptoms of what is commonly called white diarrhea in young chicks. Ontario Dept. Agr. Bul. 163 (Mar.), pp. 10, 11.

(18) Rettger, L. F., and Harvey, S. C.
1908. Fatal septicemia in young chickens, or "white diarrhea." Jour. Med. Research, 18, No. 2 (May), pp. 277–290.

(19) Milks, H. J.
1908. A bacterial disease of young chicks. La. Sta. Bul. 108 (Aug.), pp. 8–11.

(20) Dryden, J.
1908. Incubation experiments. Oreg. Sta. Bul. 100 (Aug.), pp. 32.

(21) Pernot, E. F.
1908. An investigation of the mortality of incubator chicks. Oreg. Sta. Bul. 103 (Dec.), pp. 16.

(22) Hadley, P. B.
1909. Studies in avian coccidiosis.—I, White diarrhea of chicks. Centbl. Bakt. [etc.], 1, Abt., Orig., 50, No. 3 (May), pp. 348–353.

(23) Morse, G. B.
1909. So-called white diarrhea of chicks. Rel. Poultry Jour. 16, No. 5, (July), pp. 570, 571, 593–597.

(24) Rettger, L. F.
1909. Further studies on fatal septicemia in young chickens, or "white diarrhea." Jour. Med. Research, 21, No. 1 (July), pp. 115–123.

(25) Hadley, P. B., and Kirkpatrick, W. F.
1909. Further investigations upon white diarrhea of chicks. Successful Poultry Jour., 14, No. 4 (Oct.), pp. 18, 19.

(26) Rettger, L. F., and Stoneburn, F. H.
1909. Bacillary white diarrhea of young chicks. [First report.] Conn. Storrs Sta. Bul. 60 (Dec.), pp. 33–57.

(27) Morse, G. B.
1909. Diseases of poulty with special reference to liver disease and what is commonly called "white diarhoea." Ontario Poultry Inst. Ann. Rpt., 4, pp. 21–34.

(28) [Higgins, C. H.]
1909. White diarrhoea of young chicks. Canada Expt. Farms Rpts. 1908 [Mar.], pp. 262, 263.

(29) Rettger, L. F.
1910. White diarrhea in chicks. Amer. Poultry World, 1, No. 3 (Jan.), pp. 160, 213.

(30) Morse, G. B.
1910. Bacterial enteritis. W. Va. State Bd. Agr. Rpt. (Sept.), p. 23.

(31) Westphal, W.
1910. Der weisse durchfall, seine ursachen und heilung. Deut. Landw. Geflügel Ztg., No. 44; abs. in Berlin. Tierärztl. Wchnschr., 26, No. 50 (Dec.), p. 1001.

(32) Platt, F. L.
1911. How to prevent and cure white diarrhea in chickens. Rel. Poultry Jour., 17 No. 11 (Jan.), pp. 1154, 1164–1168.

(33) Pearl, R., Surface, F. M., and Curtis, M. R.
1911. Bacillary white diarrhea. Me. Sta. [Doc.] 398 (Feb.), pp. 186–192.

(34) Jones, F. S.
1911. Fatal septicemia or bacillary white diarrhea in young chickens. N. Y. State Vet. Col. Rpt. 1909–10 [Feb.], pp. 111–129.

(35) Rettger, L. F., and Stoneburn, F. H.
1911. Bacillary white diarrhea of young chicks. Second Report. Conn. Storrs Sta. Bul. 68 (Apr.), pp. 279–301

(36) Rettger, L. F
1911. Bacillary white diarrhea of young chicks. Abs. in Science, 33, No. 849 (Apr.), pp. 547, 548.

(37) Gage, G. E.
1911. Notes on ovarian infection with *Bacterium pullorum* (Rettger) in the domestic fowl. Jour. Med. Research, 24, No. 3 (June), pp. 491–496.

(38) Jones, F. S.
1912. Further studies on bacillary white diarrhea in young chickens. N. Y. State Vet. Col. Rpt., 1910–11 (Feb.), pp. 69–88.

(39) Rettger, L. F., Kirkpatrick, W. F., and Stoneburn, F. H.
1912. Bacillary white diarrhea of young chicks. Third Report. Conn. Storrs Sta. Bul. 74 (Dec.), pp. 153–185.

(40) Jones, F. S.
1913. An outbreak of an acute disease in adult fowls due to *Bacterium pullorum*. N. Y. State Vet. Col. Rpt. 1911–12 (Jan.), pp. 140–148; Jour. Med. Research, 27, No. 4 (Jan.), pp. 471–479.

(41) ———
1913. The value of the macroscopic agglutination test in detecting fowls that are harboring *Bacterium pullorum*. N. Y. State Vet. Col. Rpt. 1911–12 (Jan.), pp. 149–158; Jour. Med. Research, 27, No. 4 (Mar.), pp. 481–495

(42) Bushnell, L. D., and Maurer, O.
1913. The use of milk cultures of *B. bulgaricus* in the prevention and treatment of bacillary white diarrhea of young chicks. Amer. Vet. Rev., 44, No. 2 (Nov.), pp. 194–207.

(43) Jones, F. S.
1913. Bacillary white diarrhea in chickens. Amer. Vet. Med. Assoc. Proc., 1912, pp. 379–388.

(44) Gage, G. E., Paige, B. H., and Hyland, H. W.
1914. On the diagnosis of infection with *Bacterium pullorum* in the domestic fowl. Mass. Sta. Bul. 148 (Apr.), pp. 20.

(45) Rettger, L. F., Kirkpatrick, W. F., and Jones, R. E.
1914. Bacillary white diarrhea of young chicks. Fourth Report. Conn. Storrs Sta. Bul. 77 (June), pp. 263–309.

(46) ———
1914. Ovarian infection in the domestic fowl and direct transmission of disease to the offspring. Jour. Expt. Med., 19, No. 6 (June), pp. 552–561.

(47) Horton, G. D.
1914. Sulphocarbolates in the treatment of white diarrhea (bacillary form) of young chicks. Amer. Vet. Rev., 46, No. 3 (Dec.), pp. 321, 322.

(48) Smith, T., and TenBroeck, C.
1915. Agglutination affinities of a pathogenic bacillus from fowls (fowl typhoid) (*Bacterium sanguinarium* Moore) with the typhoid bacillus of man. Jour. Med. Research, 31, No. 3 (Jan.), p.p503–521.

(49) ——— ———
1915. A note on the relation between *B. pullorum* (Rettger) and the fowl typoid bacillus (Moore). Jour. Med. Research, 31, No. 3 (Jan.), pp. 547–555.

(50) Rettger, L. F., Kirkpatrick, W. F., and Card, L. E.
1915. Chickens: Milk feeding and its influence on growth and mortality.—Comparative study of the value of sweet and sour milk. Conn. Storrs Sta. Bul. 80 (Apr.), pp. 28.

(51) Gage, G. E., and Paige, B. H.
1915. Bacillary white diarrhea (*Bacterium pullorum* infection) in young chicks in Massachusetts. Mass. Sta. Bul. 163 (Aug.), pp. 48.

(52) Anon.
1915. Campaign to eliminate bacillary white diarrhea. Mass. Sta. Circ. 56 (Sept.), p. 1.

(53) Kaupp, B. F.
1915. White diarrhea. N. C. Sta. Bul. 233 (Sept.), pp. 13, 14.

(54) Rettger, L. F., Kirkpatrick, W. F., and Jones, R. E.
1915. Bacillary white diarrhea of young chicks: Its eradication by the elimination of infected breeding stock. Fifth Report. Conn. Storrs Sta. Bul. 85 (Dec.), pp. 151–167.

(55) Jones, R.
1915. Practical application of the agglutination test. Jour. Amer. Assoc. Instr and Invest. Poultry Husb., 2, No. 3 (Dec.), pp. 22, 23.

(56) Pearl, R., Surface, F. M., and Curtis, M. F.
1915. Bacillary white diarrhea. *In* Diseases of Poultry. New York: Macmillan Co., pp. 287–300.

(57) Kaupp, B. F.
1916. Some further studies of chick mortality. N. C. Sta. Bul. 235 (Jan.), pp. 3–11, 15.

(58) Rettger, L. F., Hull, T. G., and Sturges, W. S.
1916. Feeding experiments with *Bacterium pullorum*.—The toxicity of infected eggs. Jour. Expt. Med., 23, No. 4 (Apr.), pp. 475–489.

(59) Taylor, W. J.
1916. An outbreak of foul typhoid. Jour. Amer. Vet. Med. Assoc., 49, No. 1 (Apr.), pp. 35–49.

(60) Rettger, L. F.
1916. Occurrence and significance of *Bacterium pullorum* in eggs. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 2, No. 8 (May), pp. 62, 63.

(61) Gage, G. E., and Martin, J. F.
1916. Notes on the histo-pathology of the intestines of young chicks infected with *Bacterium pollorum*. Jour. Med. Research, 34, No. 2 (May), pp. 149–155.

(62) Anon.
1916. Campaign to eliminate bacillary white diarrhea. Mass. Sta. Circ. 65 (Sept.), p. 1.

(63) Rettger, L. F., Kirkpatrick, W. F., and Jones, R. E.
1916. Bacillary white diarrhea of young chicks.—VI, Second progress report on the elimination of infected breeding stock. Conn. Storrs Sta. Bul. 88 (Oct.), pp. 247–254.

(64) Horton, G. D.
1916. Apparent recovery of a hen infected with bacillary white diarrhea as determined by the macroscopic agglutination test. Jour. Bact., 1, No. 6 (Nov.), pp. 625, 626.

(65) Rettger, L. F., and Koser, S. A.
1917. A comparative study of *Bacterium pullorum* (Rettger) and *Bacterium sanguinarium* (Moore). Jour. Med. Research, 35, No. 3 (Jan.), pp. 443–458.

(66) Lunn, A. G.
1917. Bacillary white diarrhea. Jour. Mass. Poultry Soc., 1, No. 2 (Jan.), pp. 13–15.

(67) Ward, A. R., and Gallagher, B. A.
1917. An intradermal test for *Bacterium pullorum* infection in fowls. U. S. Dept. Agr. Bul. 517 (Feb.), pp. 15.

(68) Beach, J. R.
1917. Bacillary white diarrhea or fatal septicemia of chicks and coccidiosis or coccidial enteritis of chicks. Calif. Sta. Circ. 162 (Mar.), pp. 8.

(69) Goldberg, S. A.
1917. A study of the fermenting properties of *Bacterium pullorum* (Rettger) and *Bacterium sanguinarium* (Moore). Jour. Amer. Vet. Med. Assoc., 51, No. 2 (May), pp. 203–210; N. Y. State Vet. Col. Rpt. 1915–16 (May), pp. 283–293.

(70) Jones, R. E.
1917. Practical application of the agglutination test. Jour. Amer. Assoc. Instr. and Invest. Poultry Husb., 3, No. 8 (May), pp. 63, 64.

(71) Whitaker, H. D.
1917. Bacillary white diarrhea of chicks. Wash. State Col. Ext. Serv. Poultry Ext. Circ. 14 (June), p. 1.

(72) Krumwiede, C., jr., and Kohn, L. A.
1917. Studies on the paratyphoid-enteritidis group.—IV. The differentiation of the members of the paratyphoid-enteritidis group from *B. typhosus* with special reference to the anaerogenic strains and observations on the fermenting characteristics of the avian types. Jour. Med. Research, 36, No. 3 (July), pp. 509–518.

(73) Hadley, P. [B.], Caldwell, D. W., Elkins, M. W., and Lambert, D. J.
1917. Infections caused by *Bacterium pullorum* in adult fowls. R. I. Sta. Bul. 172 (Nov.), pp. 40.

(74) Kaupp, B. F.
1917. White diarrhea. *In* Poultry Diseases. Chicago: Amer. Vet. Pub. Co., 1917, 2. ed., rev. and enl., pp. 119–124.

(75) Hadley, P. [B.].
1918. Regarding limitations in the interpretation of positive agglutination tests of *Bacterium pullorum* infections. Jour. Amer. Assoc., Instr. and Invest. Poultry Husb., 4, No. 6 (Mar.), pp. 42–44.

(76)——— et al.
1918. The colon-typhoid intermediates as causative agents of disease in birds.—I, The paratyphoid bacteria. R. I. Sta. Bul. 174 (May), pp. IV + 216.

(77) Rettger, L. F., Kirkpatrick, W. F., and Card, L. E.
1919. Bacillary white diarrhea of young chicks.—VII. Ovarian infection of the adult fowl and transmission of the disease through the oviduct. Conn. Storrs Sta. Bul. 101 (Jan.), pp. 73–88.

(78) Brown, C. E.
1919. Artificial v. natural incubation: [Influence on bacillary white diarrhea of chicks]. Minn. Sta., Crookston Substa. Rpt., 1917–18, (Apr.), pp. 84–86.

(79) Scherago, M., and Benson, J. P.
1919. Experiments on the intradermal test for *Bacterium pullorum*. Cornell Vet., 9, No. 2 (Apr.), pp. 111–119; N. Y. Vet. Col. Rpt. 1918–19 [1920], pp. 183–191.

(80) Richardson, A. W.
1919. White diarrhea of fowls. N. H. Univ. [Agr.] Ext. Circ. 44 (June), pp. 4.

(81) Mulsow, F. W.
1919. Avian paratyphoid bacilli: A comparative study of *B. pullorum* and *B. sanguinarium*. Jour. Infect. Diseases, 25, No 2, pp. 135–162.

(82) Durant, A. J.
1920. White diarrhea in chickens. Mo. Agr. Col. Ext. Circ. 85 (Aug.), pp. 4.

(83) Ward, A. R., and Gallagher, B. A.
1920. Bacillary white diarrhea. *In* Diseases of Domesticated Birds. New York: Macmillan Co., pp. 68–80.

(84) Spray, R. S., and Doyle, L. P.
1921. Paratyphoid bacilli from chicks. Jour. Infect. Diseases, 28, No. 1 (Jan.), pp. 43–47.

(85) Anon.
1921. White diarrhea tests. N. H. Sta. Bul. 198 (May), p. 22.

(86) Bagué, J.
1921. La diarrea blanca. P. R Dept. Agr. and Labor Sta. Circ. 46, Spanish ed. (Aug.), pp. 4.

(87) Stafseth, H. J.
1921. Bacillary white diarrhea of fowls. Mich. Sta. Quart. Bul. 4, No. 2 (Nov.), pp. 41, 42.

(88) Lewis, H. R.
1921. Control of bacillary white diarrhea. N. J. Stas. Rpt. 1920, pp. 127-131.

(89) Anon.
1921. White diarrhea in chicks. Iowa Agr. Col. Ext. Serv. 1 [1921?], Suggestion No. 5, p. 1.

(90) Lewis, H. R.
1921. Contagious white diarrhoea. *In* Productive Poultry Husbandry. Philadelphia and London: J. B. Lippincott Co., 4. ed., rev. and enl., pp. 364, 365.

(91) Gage, G. E.
1922. Control of bacillary white diarrhea, 1920-21. Mass. Sta. Control Ser. Bul. 18 (Mar.), pp. 8.

(92) Thompson, W. C., and Dodson, L. S.
1922. Ovarian infection by *Bacterium pullorum* (Bacillary white diarrhea). N. J. Stas. Bul. 363 (Mar.), pp. 50-53.

(93) Gage, G. E.
1922. Concerning the diagnosis of *Bacterium pullorum* infection in the domestic fowl. Mass. Sta. Tech. Bul. 5 (Aug.), pp. 61-88.

(94) Beach, J. R., and Freeborn, S. B.
1922. White diarrhoea of chicks. Calif. Sta. Circ. 251 (Aug.), pp. 25, 26.

(95) Gage, G. E., and Flint, O. S.
1922. Control of bacillary white diarrhea, 1921-22. Mass. Sta. Control Ser. Bul. 22 (Dec.), pp. 8.

(96) Doyle, L. P.
1922. Bacillary white diarrhea in chicks. Purdue Agr. Ext. Leaflet 73, rev. ed. (Dec.), pp. 4.

(97) Stafseth, J. H.
1922. [Bacillary white diarrhea testing.] Mich. Sta. Rpt. 1922, pp. 196-198.

(98) Kaupp, B. F.
1922. Bacillary white diarrhea. *In* Poultry Diseases. Chicago: Alexander Eger, 3. ed., rev. and enl., pp. 173-175

(99) Beaudette, F. R., Bushnell, L. D., and Payne, L. F.
1923. Study of an organism resembling *Bact. pullorum* from unabsorbed yolk of chicks "dead in shell." Jour. Infect. Diseases, 32, No. 2 (Feb.), pp. 124-132.

(100) Truche, C.
1923. De la typhose aviaire. Bul. Soc. Cent. Méd. Vét., 99, No. 8 (Apr.), pp. 138-155; Ann. Inst. Pasteur, 37, No. 5 (May), pp. 478-497.

(101) Truche, C., and Urbain, A.
1923. Sensibilisatrices dues a *Bacterium pullorum* et a *Bacterium sanguinarium*. Compt. Rend. Soc. Biol. [Paris], 88, No. 17 (May), pp. 1275, 1276.

(102) Gage, G. E., and Flint, O. S.
1923. Control of bacillary white diarrhea, 1922-23. Mass. Sta. Control. Ser. Bul. 23 (Sept.), pp. 10.

(103) Anon.
1923. Bacillary white diarrhea of chicks. Ill. Sta. Circ. 273 (Sept.), pp. 4.

(104) Hitchner, E. R.
1923. The macroscopic agglutination test as influenced by the fatty content of the blood serum. Jour. Amer. Vet. Med. Assoc., 63, No. 6 (Sept.), pp. 759-763.

(105) Beaudette, F. R., Bushnell, L. D., and Payne, L. F.
1923. Relation of *Bacterium pullorum* to hatchability of eggs. Jour. Infect. Diseases, 33, No. 4 (Oct.), pp. 331-337.

(106) St. John-Brooks, R., and Rhodes, M.
1923. The organisms of the fowl typhoid group. Jour. Path. and Bact., 26, No 4 (Oct.), pp. 433-439.

(107) Beaudette, F. R.
1923. Agglutinins for *Bacterium pullorum* in hens' eggs. Jour. Immunol., 8, No. 6 (Nov.), pp. 493-497.

(108) ———
1923. Single tube method for determining carriers of *Bacterium pullorum*. Jour. Amer. Vet. Med. Assoc., 64, No. 2 (Nov.), pp. 225-227.

(109) Stafseth, H. J.
1923. [Bacillary white diarrhea.] Mich. Sta. Rpt. 1923, p. 206.

(110) Bergey, D. H., et al.
1923. Bergey's manual of determinative bacteriology. Baltimore: Williams & Wilkins Co., 1923, pp. XII + 461.

(111) Kaupp, B. F., and Dearstyne, R. S.
1923. Diarrhea of chicks. N. C. Sta. Rpt. 1923, p. 69.

(112) Richardson, A. W.
1924. White diarrhea work. N. H. Sta. Bul. 212 (Jan.), p. 36.

(113) Slocum, R. B.
1924. The accredited hatchery as a factor fn standardizing market chickens and eggs. Poultry Sci., 3 (1923-24), No. 2 (Jan.), pp. 60-64.

(114) Stafseth, H. J., and Mallmann, W. L.
1924. Prevalence of bacillary white diarrhea. Mich. Sta. Quart. Bul., 6, No. 3 (Feb.), pp. 130-132.

(115) Hartwell, B. L.
1924. [White diarrhea.] R. I. Sta. Rpt. 1923 (Feb.), p. 12.

(116) Jorgenson, G. E.
1924. *Bacillus acidophilus* and immune serum in bacillary white diarrhea of chicks. North Amer. Vet., 5, No. 2 (Feb.), pp. 63-65.

(117) Beaudette, F. R.
1924. Diseases of baby chicks. N. J. Stas. Hints to Poultrymen, 12, No. 6 (Mar.), pp. 4.

(118) Brunett, E. L.
1924. Bacillary white diarrhea of chicks. Cornell Vet., 14, No. 2 (Apr.), p. 92.

(119) Johnson, W. T.
1924. Contagious white diarrhea. West. Wash. Sta. Bimo. Bul. 11, No. 6 (Mar.), pp. 124-127.

(120) Beach, B. A., and Halpin, J. G.
1924. White diarrhea in poultry. Wis. Sta. Bul. 362 (Mar.), p. 109.

(121). Steiner, A. J.
1924. Bacillary white diarrhea. Ky. Sta. Circ. 33 (Apr.), pp. 8.

(122) Allen, W. H.
1924. Why chicks die. N. J. Stas. Hints to Poultrymen, 12, No. 7 (Apr.), pp. 4.

(123) Beaudette, F. R.
1924. A description of the method for collecting blood samples from breeding stock to be tested for "carriers" of bacillary white diarrhea. N. J. Stas. Hints to Poultrymen, 12, No. 9 (June), pp. 4.

(124) Bushnell, L. D., and Hinshaw, W. R.
1924. Bacillary white diarrhea. Kans. Sta. Circ. 106 (July), pp. 33, 34.

(125) Gage, G. E., and Flint, O. S.
1924. Control of bacillary white diarrhoea, 1923-24. Mass. Sta. Control Ser. Bul. 27 (July), pp. 8.

(126) Knight, E.
1924. Blood agglutination tests on adult fowls in respect of "bacillary white diarrhoea" or infectious septicaemia of young chicks. Jour. Path. and Bact., 27, No. 3 (July), pp. 231, 232.

(127) Jones, R. E.
1924. Bacillary white diarrhoea. Conn. Agr. Col. Ext. Bul. 78 (Aug.), pp 4.

(128) Waite, R. H.
1921. Practical methods to control and prevent white diarrhea in chicks. Md. Sta. Bul. 244 (Aug.), pp. 27, 28.

(129) Newsom, I. E.
1924. Bacillary white diarrhoea of chicks. Colo. Sta. [Bul.] 293 (Sept.), pp. 8.

(130) Edington, J. W
1924. The bacteriological study of fowl typhoid and allied infections, with special reference to three epidemics. Jour. Path. and Bact., 27, No. 4 (Oct.), pp. 427–437.

(131) Panisset, L., and Verge, J.
1924. Sur une épizootie de diarrhée blanche bacillaire des poussins. Rev. Gén. Méd. Vét., 33, No. 385, pp. 19–21.

(132) Anon.
1924. [Bacillary white diarrhea.] Kans. Sta. Bien. Rpt. 1923–24, pp. 123, 124–126.

(133) Eriksen, S.
1924. [Bacillary white diarrhea.] *In* Mo. State Poultry Assoc. Year Book 1923. Mountain Grove: Mo. State Poultry Assoc., [1924], pp. 31–36.

(134) Fuller, J. W.
1924. The intradermal test for detecting fowls carrying *Bacterium pullorum*. N. Y. State Vet. Col. Rpt. 1922–23, pp. 59–61.

(135) Kaupp, B. F.
1924. [Effect of lactic acid on disease-producing germs of fowls.] N. C. Sta. Rpt. 1924, pp. 64.

(136) Baker, H. R.
1925. Studies on bacillary white diarrhoea in poultry in Delaware. Del. Sta. Bul. 139 (Jan.), p. 14.

(137) Bushnell, L. D., and Patton, J. W.
1925. The use of vaccines in poultry diseases. Poultry Sci., 4 (1924–25), No. 2 (Jan.), pp. 64–73.

(138) Dakan, E. L.
1925. The new poultry A B C's: Ohio should have accredited baby chicks. Ohio Farmer, 155, No. 3 (Jan.), pp. 20, 21.

(139) Merrill, L. S.
1925. White diarrhea testing. Me. Agr. Col. Ext. Bul. 150 (Feb.), p. 49.

(140) Anon.
1925. College makes new record in first year fowl tests. N. J. Agr., 7, No. 2 (Feb.), pp. 3, 4.

(141) [Eriksen, S.]
1925. Bacillary white diarrhea. Avian Path. [Mo. Poultry Sta.], 2, No. 4, (Feb.), pp. 9–11.

(142) ———
1925. Bacillary white diarrhea eradication demonstration. Avian Path. [Mo. Poultry Sta.], 2, No. 8 (June), p. 23.

(143) Graham, R., Boughton, I. B., and Tunnicliff, E. A.
1925. Blood test aids control of chick disease. Ill. Sta. Rpt. 1924 (June), pp. 87, 88.

(144) Clark, G. L.
1925. Bacillary white diarrhea. Vet. Med., 20, No. 6 (June), p. 280.

(145) Bransfield, P. E.
1925. Control of bacillary white diarrhoea. 1924–25. Mass. Sta. Control Ser. Bul. 31 (July), pp. 7.

(146) Brunett, E. L.
1925. Bacillary white diarrhea; fatal septicemia of chicks Cornell Vet., 15, No. 3 (July), pp. 303–314.

(147) Waite, R. H.
1925. A simple and effective system of management for the control of bacillary white diarrhea. Md. Sta. Bul. 274 (July), pp. 20.

(148) Canfield, H.
1925. The effects of bacillary white diarrhea: Experiments show heavy losses from this disease in poultry flocks. Mich. Sta. Quart. Bul., 8, No. 1 (Aug.), pp. 31, 32.

(149) Beaudette, F. R.
1925. Bacillary white diarrhea. Poultry Sci., 4, No. 6 (Sept.), pp. 205–224.

(150) Kaupp, B. F., and Dearstyne, R. S.
1925. The effects of lactic acid on *B. pullorum*, *B. avisepticus* and *B. sanguinarium*, and its possible rôle in the control of intestinal diseases of poultry. Poultry Sci., 4, No. 6 (Sept.), pp. 242–249.

(151) Mallmann, W. L.
1925. *Bacterium pullorum* studies. Mich. Sta. Tech. Bul. 68 (Oct.), pp. 29.

(152) McCulloch, C.
1925. White diarrhea. South. Planter, 86, No. 20 (Oct.), pp. 21, 22, 23.

(153) Hinshaw, W. R.
1925. Control of bacillary white diarrhea. North Amer. Vet., 6, No. 11 (Nov.), pp. 31–34.

(154) Jull, M. A.
1925. Poultry problems discussed. Mich. Farmer, 165, No. 20 (Nov.), p. 23.

(155) Roberts, E., and Card, L. E.
1925. Resistance of chicks to bacillary white diarrhea. Amer. Soc. Anim Prod. Proc. (Dec.), pp. 113–115.

(156) Doyle, T. M.
1925. Bacillary white diarrhoea of chicks. Jour. Compar. Path. and Ther., 38, No. 4 (Dec.), pp. 266–282.

(157) Feldman, W. H.
1925. Recent progress in medical science. Jour. Amer. Vet. Med. Assoc., 68, No. 3 (Dec.), pp. 343–354.

(158) Anon.
1925. Blood test aids control of chick disease. Ill. Sta. Rpt. 1924, pp. 87, 88.

(159) Anon.
1925. Diarrhea resistance sought in chickens. Ill. Sta. Rpt. 1924, pp. 88, 89.

(160) Gwatkin, R.
1925. Bacillary white diarrhea in chicks and *Salmonella pullora* infection in adult fowl. Ontario Vet. Col. Rpt. 1924, pp. 68–70.

(161) Rice, J. E., and Botsford, H. E.
1925. Bacillary white diarrhea. *In* Practical Poultry Management. New York: John Wiley & Sons (Inc.); London: Chapman & Hall (Ltd.), pp. 384–386.

(162) Anon.
Bacillary white diarrhea. Purdue Agr. Ext., County Agent News Notes, [Oct., 1924?], pp. 1, 2.

(163) Kaupp, B. F.
1914. White diarrhea. *In* Poultry Diseases and Their Treatment. Chicago: Amer. Jour. Vet. Med., pp. 93–99.

(164) Anon.
1926. New Jersey testing for white diarrhoea. Amer. Agr., 117, No. 1. (Jan.), p. 495.

(165) Stafseth, H. J.
1924. [Investigations of the agglutination test for *B. pullorum*.] Mich. Sta. Rpt. 1924, pp. 186, 187.

(166) Anon.
1926 Bacillary white diarrhea control. North Amer. Vet., 7, No. 1 (Jan.), pp. 30–32.

(167) Anon.
1925 [Accrediting poultry.] Poultry Sci., 4, No. 5 (July), pp. 184, 185.

(168) Van Es, L.
1920. Bacillary white diarrhea in chicks. Nebr. Col. Agr. Ext. Bul. 58, pp. 4.

(169) Anon.
1925. Control of bacillary white diarrhea [Questionnaire]. Compiled by Poultry Office, Animal Husbandry Division, U. S. D. A. Bureau of Animal Industry, pp. 10 (Mimeograph).

(170) Anon.
1925. A uniform plan of accreditation and certification of poultry as adopted at the standardization conference held at Manhattan, Kans., August 10–11, 1925. U. S. D. A. Bureau of Animal Industry, pp. 3 (Mimeograph).

(171) Kaupp, B. F.
1912. White diarrhoea. Colo. Sta. Bul. 185 (Sept.), pp. 19–21.

(172) Beaudette, F. R., and Black, J. J.
1926 Bacillary white diarrhea control in New Jersey, 1924–25. N. J. Stas. Bul. 425 (Feb.), pp. 22.

(173) Anon.
1926. Illinois regulations on bacillary-diarrhea free accreditation. North Amer. Vet., 7, No. 1 (Jan), p. 14.

(174) Beaudette, F. R.
1925. Diagnosis of poultry diseases. N. J. Stas. Rpt. 1924 (June), pp. 119–132.

(175) Konno, T.
1925. Bacillary white diarrhea of young chicks in Japan. Jour. Japan. Soc. Vet. Sci., 4, No. 3 (Sept.), pp. 273–288.

STATION WORK ON THE MECHANICS OF TILLAGE

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INTRODUCTION

Studies of the cost of producing agricultural commodities have developed the fact that power, whether man, animal, or mechanical, is the most expensive necessary item in such production. Kinsman, of the Bureau of Public Roads of the Department of Agriculture (*1*),[1] has shown that more primary power is used in agricultural production at present than in any other industry with the exception of transportation. Investigations made in representative sections of the country have shown further that tillage operations, which are indispensable in crop production, are among the greatest consumers of power. Efforts are therefore being made by different stations to reduce the power consumption of tillage operations as a step of primary importance in reducing the cost of agricultural production.

A critical analysis of some of the tillage problems of crop production by Nichols at the Alabama station (*2*) led to the conclusion that seed-bed preparation and cultivation are processes whose efficiency depends largely upon the degree to which tillage implements are adapted to the physical and mechanical properties of the soil. Tillage, which consists primarily of these two operations, offers a complex power utilization problem, which has an obvious bearing on the cost of agricultural production.

SEED-BED PREPARATION

Proper seed-bed preparation implies the production of a certain type or degree of tilth in soil which is more or less specifically adapted to the requirements of the optimum germination and growth of a particular crop. However, standard agronomic classifications of soils, and agronomic methods of expressing soil conditions corresponding to specified degrees of tilth have been found to provide a generally inadequate basis for the development of equipment capable of producing the desired results.

Engineering properties of soil.—In order to produce any desired state of tilth in a soil, it seems evident that certain engineering properties of the soil must be overcome to a corresponding degree. Such properties may be described as those physical and mechanical properties which directly influence the engineering operation of tillage as distinguished from those pertaining merely to certain conditions of fertility. In this connection Nichols at the Alabama station (*2*), Trullinger of the Office of Experiment Stations of this department (*3*), and others have brought out that such soil factors as cohesion, adhesion, plasticity, tensile strength, shearing strength, compressive strength, compressibility, moisture content, external and internal frictional characteristics, and possibly others, may quite materially influence the tillage operation. King at the Wisconsin station (*4*) showed, for instance, that plowing with the moldboard plow, the most widely used method in seed-bed preparation, involves the shearing, lifting, inversion, and pulverization of soil, all of which occur in opposition to the cohesive, adhesive, and frictional properties of the soil.

Tilth.—Some of the stations are endeavoring to devise methods for measuring standard degrees of soil tilth with the idea of specifically designating them for each crop or class of crops in terms of the engineering properties of any soil. The purpose of such work is to provide a more definite basis for procedure in studying the mechanics of tillage. Typical of such work is that by Hoffman at the California station (*5*), where, as a logical beginning, two general methods of measuring and designating the states of tilth of different soils, which are known to meet certain agronomic requirements, are being developed. The first of these involves the use of six screens placed one above the other, the top screen having an 8-inch mesh and decreasing in size down through 4-, 2-, 1-, and 0.5-inch sizes to the bottom screen which has a 0.25-inch mesh. The soil samples, weighing from 50 to 60 pounds and taken to the depth of tilth in an undisturbed condition, are gently deposited upon the top screen, and the percentage by weight retained by each screen is recorded. Only the 0.5- and 0.25-inch screens are

[1] Numbers in italics in parentheses refer to "References," p. 137.

shaken. Curves platted from such data so far permit the specific designation of the states of tilth in the different soils and indicate the tendencies of tillage operations in producing them. The second method measures the density of the soil before and after tillage, the resulting ratio indicating the degree of pulverization. It is understood that the work is being continued in order to measure these degrees of pulverization in terms of the engineering properties of the soils which largely govern their production.

The intensity of the resistance offered by the engineering properties of soils to their tillage is naturally the factor which governs the power requirement of the tillage operation. It has been comparatively easy to demonstrate that soils possess these properties, but attempts to evaluate them in terms of their specific influence upon the accomplishment of preconceived tillage results by the empirical testing of available tillage machines in the field, have met with relatively little success.

Plowing.—It seems generally accepted that plowing consumes more power than any other individual operation in seed-bed preparation. Attempts to reduce the power requirement to a minimum have naturally resulted in the special but nevertheless wholly empirical shaping of plow surfaces for various purposes, and have established the broad general fact that for this purpose, as well as to produce desired tillage results, different soils require different kinds and shapes of plows.

A lack of knowledge of the nature, intensity, and specific influence of the engineering properties of soil has greatly handicapped the work with plows. To begin with, their marked variations have materially influenced the power requirement of plowing. As far back as 1900 Burkett and Johnston found, in experiments at the New Hampshire station (*6*), that the same plow varied widely in draft under apparently the same visible soil conditions. In partial explanation of this Keen and Haines (*7*) showed, in experiments at the Rothamsted Experimental Station, that large variations in the resistance of a soil to plowing may exist over a short distance, regardless of chance changes in the implemental factors. Davies at the same station (*8*) showed in addition that the state of consolidation of the soil due to the nature and treatment of the previous crop had a most marked influence on the power required for plowing.

With reference to the influence of the individual soil properties, Ocock of the Illinois station (*9*), working with turf and stubble moldboards, found that the ordinary moldboard plow had a heavier draft in soil which was extremely dry or very wet than it did in soil containing only a moderate amount of moisture. Davies at the Rothamsted Experimental Station (*8*) also showed that the moisture content had a marked effect on plow draft, and suggested that there is an optimum moisture content from which an increase or decrease will result in increased draft.

In an attempt to increase the efficiency of plowing, Davidson, Fletcher, and Collins found, in studies at the Iowa station (*10*), that an increase from 2 to 3 miles per hour in the field speed of a general-purpose moldboard plow resulted in an increase in the draft of from 8 to 12 per cent, according to the nature of the soil. Doubling the speed increased the draft from 16 to 25 per cent. Although the furrows were laid more smoothly and the furrow slices were better pulverized at the higher speeds, economy was sacrificed in the greater power requirement, since the plows used were apparently not designed to fully meet the conditions of friction imposed by plowing at the higher speeds. Similar results were obtained by Jones at the Missouri station (*11*). Further experiments by Keen and Haines at the Rothamsted Experimental Station (*7*) showed that, although the power requirement of plowing increased with the speed, the percentage increase was relatively so slight that considerable saving resulted, thus indicating the different conditions which may be imposed by the varying frictional properties of soils.

Further studies by Collins (*12*) showed that the type of plow bottom did not materially influence the draft, and that an increase in speed produced about the same increase in draft with any type of plow bottom in a particular soil. The increase in draft owing to increased speed was found to be confined to that part of the total which was required for turning and pulverizing, and varied with the speed from less than one-third to about one-half the total draft of the plow within a speed range of from 2 to 4 miles per hour. Friction between soil and plow seemed therefore to cause the increased draft with increased speed. Under some plowing conditions a sharp cutting edge was of little importance and under certain conditions high speeds caused failure to scour. Here friction and adhesion were apparently the active retarding agents. Davies of the Rothamsted Experimental Station (*8*)

found, however, that a greater proportion of the net draft in plowing was used in overcoming the resistance of the soil than in turning the furrow, thus again showing the possible variation in the engineering properties of soils.

The results of a large number of plow draft tests conducted by Sjogren at the Nebraska station (*13*), at different depths and speeds, varied widely in the case of speed draft tests, but were fairly constant for the depth draft tests. An increase in plowing depth of from 5 to 10 inches resulted in an increase in draft of 27 per cent. Other tests by Sjogren (*14*) with multiple bottom plows showed that there was improper scouring in wet gumbo soils, thus indicating the influence of moisture content in enhancing the adhesive and frictional properties. The draft showed no regular tendency under these conditions except to increase with the speed. In dry sandy loam the draft of a 2-bottom plow decreased as the speed increased up to 2.25 miles per hour and then increased. The results obtained with a 3-bottom plow were the reverse of those obtained with a 2-bottom plow in the same soil. The draft of a 2-bottom plow in moist clay loam was less at a speed of 4.66 miles per hour than at 2.97 miles per hour. The draft of a 5-bottom plow increased as the depth of plowing increased from 4.5 to 7 inches and then decreased up to an 8.5-inch depth. Ocock at the Illinois station (*9*) found an increased draft with increasing depth in all cases but a decreased draft per square inch of cross section of furrow with increasing depth. A 14-inch plow showed the lowest average draft per square inch of cross section, a 16-inch plow the highest, and an 18-inch plow a draft intermediate between the other two.

Davies at the Rothamsted Experimental Station (*8*) found a linear relation between draft and depth of furrow, except when the previous crop was a root crop, resulting in a decrease in draft at depths greater than 6 to 8 inches. A linear relation was also established between draft and width of furrow, increasing in some cases and decreasing in others. The double plow was found to be a more efficient implement in this respect than the single plow with similar fittings and moldboard.

These typical plowing results seem to indicate that the engineering properties of soils exert a definite influence on plowing, regardless of the construction, weight, or speed of operation of the plows used, and this influence appears to vary mainly as the soil properties vary, with only minor regard to changes in the same type of plow.

CULTIVATION

The engineering properties of soils have also been found to be of considerable importance in cultivation or surface tillage. The draft of such tools is heavy, and efforts to reduce it are being constantly made. The disk harrow is a typical cultivating tool and is one having the heaviest draft.

Disking.—Tests of the draft of disk harrows at the California station (*15*) by Hoffman and Stirniman showed that at speeds ranging from 0.5 to 6.1 miles per hour, there was no increase in draft with an increase in speed, and in some cases there was a slight but definite decrease. Friction apparently was a minor factor in the draft in these tests. With a set of angle of gangs of 18°, cutaway disks pulled 15.5 per cent harder than full disks and the draft apparently increased as the angle at which the gangs were set increased from 3 to 23°. Here undoubtedly the factor of increased friction between metal and soil entered in sufficiently to profoundly influence the results.

Both Collins (*16*) and Stirniman (*17*), in work at the Iowa station, showed that the full disk harrow required less draft per foot of width than did the spader or cutaway disk when doing the same quality of work on similar soils. Collins found that the cutaway disk penetrated more deeply than the full disk, causing an increase of from 10 to 20 per cent in the draft according to the soil conditions. Stirniman showed that the cutaway disk had a greater draft even at smaller angles of inclination than the full disks under similar conditions, thus emphasizing the variable resistance of soil frictional and shearing properties to cultivating tools of different shapes as influenced by the depth of penetration and area of contact.

Tests by Sjogren at the Nebraska station (*18*) showed that the increase in draft due to fully angling the sections of a disk harrow was about 175 per cent of the draft at no angle. The draft of the disk when weighted with 180 pounds was 60 per cent greater than when no weight was added, again bringing out particularly the influence of friction as well as that of the other resistive properties of soils on draft. Jones at the Missouri station (*19*) showed the marked influence of previous plowing of soil on the draft of a

disk harrow, which would logically be attributed to a modification of the cohesive power of the soil.

FACTORS INFLUENCING THE ENGINEERING PROPERTIES OF SOIL

There appear to be certain special characteristics of soils which can uniformly account for the nature and intensity of their engineering properties, especially as they influence the design of tillage implements. Evidence has been obtained which points to the possible bearing which the colloidal phenomena and moisture content of soil may have on its engineering properties.

Colloidal phenomena.—Moore et al. of the Bureau of Soils of this department (*20*) showed the existence of so-called ultraclay in soils, which gives every evidence of being a true colloid. When moist it is very plastic and sticky, and when dry it is as much as 10 per cent a stronger binding agent than Portland cement. Ultraclay is therefore considered to be the principal binding material of soil, giving it plasticity, cohesiveness, or hardness according to its moisture content.

Middleton of the Bureau of Soils of this department (*21*) found further that the factors influencing the binding power of soil colloids are the amount, kind, and dispersion of the colloidal material present in soils, the moisture content, and the size and grading of the noncolloidal material present. Studies by Davis of the bureau (*22*) showed that the effect of adding small quantities of soluble salts on the physical properties and the structure of soils was most pronounced in soils containing a large percentage of fine particles. The conclusion was drawn that colloid-like clay particles are most affected and in turn most affect the structure and strength of soil. It is interesting to note in this connection that Keen and Haines of the Rothamsted Experimental Station (*7*) found that variations in the draft of plows could be closely correlated with the clay content of the soil.

The resistance of hardpan in soils to the stresses introduced by tillage operations appears to represent the extreme case of soil cohesion. The relation of the occurrence of these formations in soil to colloidal phenomena and reaction seems quite probable in view of the results obtained in studies by Morison of the Rothamsted Experimental Station (*23*), and by Skeen of the University of Pennsylvania (*24*).

Jensen of this department (*25*) showed that the percentage of iron and aluminum in colloidal suspensions from soil is directly correlated with the readiness with which the soil forms a plowsole.

Moisture.—Moisture appears to have a marked influence on the cohesive, adhesive, and other engineering properties of soils not only directly but also indirectly through its influence on soil colloids. Studies by Bouyoucos at the Michigan station (*26*) on the influence of water on soil granulation, showed that water pushes the soil particles apart and thus produces a crumbling of dense masses of clods into a loose, granular structure. This is a result of swelling of the colloids and of a diminishing of the cohesive force of the particles as the water comes between them. Goldbeck and Jackson of the Bureau of Public Roads of this department (*27*) found further that, in general, moisture equivalents increase with the percentage of very fine silt and clay in soil, and that there is a fairly definite relation between the moisture equivalent and the mechanical analyis. The bearing power of most soils is not appreciably reduced by the addition of moisture up to the moisture equivalent, but saturation beyond this point causes a rapid reduction in bearing power. Thus an almost direct relation between colloidal phenomena and bearing power in soils through the medium of moisture equivalent is indicated.

External treatments.—Since moisture and colloidal phenomena appear to markedly influence the engineering properties of soils, it seems likely that certain external treatments which may influence the colloidal phenomena and the relation of moisture thereto may also indirectly influence these properties.

Russell and Keen at the Rothamsted Experimental Station (*28*) showed, for instance, that chalking of certain soils not only permitted an increase in the speed of plowing but considerably reduced the draft without change in the implemental factors. Studies by Allison at the New Jersey stations (*29*) showed that in a clay soil the effect of liming was promptly noticeable through a decrease in the modulus of rupture in cross bending. On the other hand, liming caused an increase in the modulus of rupture of a loam soil. These and similar results were taken to indicate that the action of lime on the strength properties of soils is distinctly differential, depending apparently upon the nature and type of the soil.

Beeson of the Oklahoma station (*30*) showed that lime and manure greately decreased the resistance of hardpan formations in soils to penetration.

However, Jensen of this department (*25*) found that lime appreciably decreased the percentage of inorganic colloidal suspension in soil when no organic matter was added. When organic matter was added the flocculating effect of lime was appreciably diminished, especially in clay soil. Powdered sulphur and gypsum markedly decreased the content of inorganic colloidal suspension in soil, and organic matter had no appreciable effect in counteracting the flocculating influence of these two materials. Sodium nitrate, on the other hand, markedly increased the amount of collodial suspension in soils, but organic matter appreciably decreased the deflocculating influence of this fertilizer material.

These results indicate the possible influence of external treatments on the properties of soils which influence tillage operations. They are significant, however, in that they seem to show that although organic manures, lime, and other amendments and fertilizers may reduce the influence of these properties in some soils if properly applied, they can not be used indiscriminately in the expectation that results favorable to tillage will always be obtained.

This is partially explained by studies conducted at the University of Leeds by Comber (*31*) on the flocculation of neutral and alkaline suspensions of clay, silt, and soil by lime. These showed that silt, when suspended in water, was most easily flocculated by lime if the suspension was neutral. The addition of alkali rendered flocculation more difficult. Soil clay, on the the other hand, was flocculated by lime in alkaline suspensions more readily than in neutral suspensions, resembling silicic acid and other emulsoid colloids in this respect. Further studies showed that clay, as an emulsoid, protects the larger soil particles which by themselves are suspensoids. Clay therefore ultimately imposes its emulsoid nature on the whole soil in normal cases. Fine silt soils are therefore not flocculated by lime owing to the inability of the relatively small amount of emulsoid clay to protect the large suspensoid surface exposed by the fine silt.

RELATION OF SOIL PROPERTIES TO THE DESIGN OF TILLAGE IMPLEMENTS

The engineering properties of soils are apparently definite factors, which are more or less susceptible of measurement, and which are largely governed by and vary with the colloidal phenomena and moisture content of soils. They indicate lines along which studies for the development of tillage implements might profitably proceed. Some work has been done in this connection, with special reference to soil friction.

Friction.—Friction, resulting largely from adhesion and cohesion and strongly influenced by moisture and colloidal phenomena, seems to be the most important individual power-consuming factor of tillage. From the results of experiments made at Rothamsted, Crowther and Haines (*32*) estimated that approximately one-third of the total work done in plowing is expended in overcoming the adhesive and frictional forces between the moldboard surface and the soil. This frictional force was reduced by an electrical method which depends upon the phenomenon of electroendosmose exhibited by moist soil. It was found that by virtue of the negative charge of the soil colloids, water will move through moist soil toward the negative electrodes under the action of an electric current. When a current was passed through the soil, having the moldboard of the plow as the negative electrode, the film of water formed at the soil-metal surface apparently acted as a lubricant and reduced the plowing draft. These results indicate the prominent part which moisture may play in that part of the draft of tillage due to friction.

Further studies by Haines (*33*) on surface friction between metal and a light sandy soil and a heavy loam, as they were gradually dried, showed that both soils gave a practically constant friction for a range of moisture content from 0 to 12 per cent. At this point the soils began to wet the metal and an increase in friction resulted. This increase reached a maximum at about 17 per cent moisture content in the light sandy soil. Beyond that point the metal surface was wetted so freely as to be apparently lubricated by the water film, and the friction decreased. This continued until the soil was too fluid to bear the weight of the metal slider.

The heavy loam soil, on the other hand, showed two frictional maxima instead of only one. These two maxima corresponded to the two different ways in which the soil wet the metal surface, namely, wetting without sticking and wetting with sticking. In the first case the water in the larger capillaries of the soil wet the metal surface, but the soil itself remained firm and coherent and the metal slid without being contaminated by the soil to an appreciable extent. The pores of this soil were just full of water at about 19 per cent moisture content, so that

the wetting began a little before this stage was reached and extended considerably beyond it. The second increase in the friction began as the soil began to stick to the metal. This corresponded to a definite stage of water saturation of the clay in the soil, and true surface friction ceased at this point, since the slippage took place within the top layers of the soil itself. The governing factor was then the plasticity. This seems to indicate that the soil moisture most active in connection with the frictional phenomena involved in tillage is the hygroscopic moisture.

White, at the New York Cornell station (*34*), established the fact that soil particles follow very definite paths when passing over the surface of a moldboard. With this in view and considering friction between soil and metal surfaces as the biggest consumer of power in tillage, Nichols of the Alabama station (*35*) undertook a laboratory study of the sliding of metal over soil to elucidate the principles of friction between the soil and the metal surface as they relate specifically to the power requirement of tillage. It was found possible to lay down certain fundamental laws for sliding friction between a metal surface and synthetic sand-clay mixtures varying by degrees of 25 per cent from 100 per cent sand to 100 per cent clay.

These laws, though holding only within the limits tested, were nevertheless directly applicable in explaining certain phenomena relating to the draft of plows and other tillage tools established in draft tests by others. It was found that in a dry soil, when the value of the coefficient of wetting of the soil solution was negative, i. e., when the metal surface was not wetted, and when the bearing power of the soil was less than the pressure, the sliding friction varied with the speed and with the smoothness and composition of the metal surface, and was proportional to the pressure per unit area. When the bearing power of the soil was greater than the pressure per unit area and the value of the coefficient of wetting of the soil solution was still negative, the friction was proportional to the pressure and depended upon the smoothness and composition of the metal surface. It was independent of the area of contact and the speed of sliding. When there was enough moisture present in the soil to cause it to adhere to the sliding metal surface but not enough to leave any of it on the metal surface, the friction varied with the speed, the area of contact, the pressure per unit area, the amount of colloidal matter present, the amount of water present, the temperature and viscosity of the soil solution, and the nature and composition of the metal surface. When there was enough moisture present in the soil to give an apparent lubricating effect, the friction varied with the pressure per unit area, the speed of sliding, the amount and viscosity of the soil solution, and the nature and composition of the metal surface.

These results indicate that frictional resistance, the individual factor which probably most affects the draft and quality of tillage, is therefore dynamic and constantly varying. It is affected primarily by the moisture content and size of particles of the soil, and therefore, at the stage where plowing becomes most difficult, its magnitude is determined largely by the colloidal phenomena of the soil.

The importance of these factors in the practical design of tillage tools is obvious. For instance, in the normally dry soil first noted, the plow shape which will give the lowest speed of soil over the metal surface and the lowest pressure per unit area of contact will give the least frictional resistance. Soils of this nature are, however, usually plowed with a steep moldboard, which is directly opposed to the indications of the laws of friction as applied to proper practice. The second condition noted would also seem to require gentler moldboard slopes for minimum frictional resistance.

These results would therefore seem to have considerable bearing on those obtained in the experiments enumerated above on the effect of speed on plowing draft. Obviously in normally dry soil the draft would increase with the speed. However, when the bearing power of the soil is greater than the pressure per unit area, speed would have little influence on the draft of normally dry soil and would again become a factor of importance only when the soil became wet enough to become sticky.

The most significant feature of these results, however, especially from the standpoint of further study, seems to be that the frictional resistance depends upon the nature and composition of the metal surface throughout the entire range of soil types and moisture contents studied. The practical solution of the problem involved in the sticking of soil to plow metal and in the frictional resistance to plowing seems to be closely allied with the physical properties of the metal surface. It was shown that the factors favoring

such sticking action are more active the greater the tendency of the soil solution to wet and spread on the metal surface in soils which are still not too wet to plow. This tendency is designated and measured by the so-called coefficient of spreading of the soil solution. Attempts to modify the soil solution by external treatments, so as to reduce its tendency to spread on and wet the surfaces of available plow metals, may offer possibilities. The more practical and immediate solution of the problem would, however, seem to lie in the development of plow metal surfaces having such a molecular composition as to offer a maximum resistance to wetting by the soil solution. That this is not impracticable is indicated by the existence of noncorrosive steels which are used in cutlery, hand tools, and certain machine parts.

Apparently such a development of the composition of plow metal surfaces should also have an influence on the tendency of such surfaces to wear in service. It is interesting to note in this connection that the wear of the metal surfaces of tillage tools does not always conform to the accepted principles of the wear of metals For instance, Hoffman of the California station (*36*) found, in wearing tests of manganese steel, soft center steel, and chilled cast-iron plowshares in soils, that the least wear was shown by the chilled cast iron and the most by the manganese steel. In other words, the hard and extremely tough manganese steel showed greater wear by frictional contact with soil than the hard but extremely brittle chilled cast iron. It seems quite conceivable that the molecular composition of the chilled cast iron was of such a nature as to practically prevent the solution of the particular soils plowed from spreading on and wetting its surface, thus reducing frictional wear to a minimum. On the other hand, the molecular composition of the manganese steel would seem to have been of such a nature as to invite the spreading on and wetting of its surface by the particular soil solution encountered, thus permitting frictional wear to reach a possible maximum.

CONCLUSIONS

The importance of the engineering properties of soil, as indicated by its resistance to various kinds of stress, on the development of machinery capable of producing desired tillage results with a minimum utilization of power seems evident. Apparently the more active of these properties, from the standpoint of tillage, are in turn governed largely by the moisture content and the colloidal phenomena of soil.

Fertilizer and cropping treatments to increase the productiveness of soils also seem to exert a marked influence on these engineering properties, when properly applied, and may therefore facilitate the development of tillage machines capable of producing desired tillage results.

A consideration of these important soil characteristics in connection with certain of the fundamental laws of physics seems especially to throw considerable light on the design of tillage implements capable of producing desired tillage results with a minimum utilization of power. For example, the laws of physics governing the friction between soil and metal surfaces appear important in this connection, especially when the possibility of wide modification and variation of the physical properties of the metal surfaces is considered.

The importance of first recognizing and taking proper advantage of natural or artificial influences favorable to tillage seems evident. The opportunity for further development of research in the mechanics of tillage appears to lie largely in a closer cooperation by the agricultural engineer with the agronomist, soils physicist, and the metallurgist.

REFERENCES

(1) An appraisal of power used on farms in the United States. C. D. Kinsman. U. S. Dept. Agr. Bul. 1348. 1925.
(2) An analysis of soil dynamics factors affecting the operation of tillage and tractor machinery. M. L Nichols. Amer. Soc. Agr. Engin. Trans., 17 (1923), pp. 174–184.
(3) Soil colloids and tillage. R. W. Trullinger. Agr. Engin., 6 (1925), No. 3, pp. 61–63; 4, pp. 84–87.
(4) A textbook of the physics of agriculture. F. H. King. Madison, Wis. 1901.
(5) Calif. Sta. Rpt. 1923, pp. 50, 51.
(6) Dynamometer tests with farm implements. C. W Burkett and F. S. Johnston. N. H. Sta. Bul. 87, pp. 122–124. 1901.
(7) Studies in soil cultivation, I–III. B. A. Keen and W. B. Haines. Jour. Agr. Sci. [England], 15 (1925), No. 3, pp. 375–406.
(8) A preliminary investigation into the draft of the plough. W. M. Davies. Jour. Agr. Sci [England], 14 (1924), No. 3, pp. 370–406.
(9) The draft of plows. C. A. Ocock. Amer. Soc. Agr. Engin. Trans., 6 (1912), pp. 13–30.
(10) Influence of speed upon the draft of plow. J. B. Davidson, L. J. Fletcher, and E. V. Collins. Amer. Soc. Agr. Engin. Trans., 13 (1919), pp. 69–77.
(11) Mo. Sta. Bul. 179, p. 14. 1921.
(12) Factors influencing the draft of plows. E. V. Collins. Amer. Soc. Agr. Engin. Trans., 14 (1920), pp. 39–55.
(13) Nebr. Sta. Rpt. 1921, p. 23.
(14) Drafts of engine-drawn implements. O. W. Sjogren. Amer. Soc. Agr. Engin. Trans., 11 (1917), pp. 212–218.
(15) Calif. Sta. Rpt. 1922, p. 21.
(16) Iowa Sta. Rpt. 1921, pp. 8, 9; 1922, p. 7; also in Agr. Engin., 3 (1922), No. 3, pp. 44, 45.

(17) Draft test of farm machinery. E. J. Stirniman. Amer. Soc. Agr. Engin. Trans., 12 (1918), pp. 9–25.
(18) Nebr. Sta. Rpt. 1921, pp. 23, 24.
(19) Mo. Sta. Bul. 189, p. 20. 1921.
(20) Methods for determining the amount of colloidal materials in soils. C. J. Moore et al. Jour. Indus. and Engin. Chem., 13 (1921), No. 6, pp. 527–530.
(21) Factors influencing the binding power of soil colloids. H. E. Middleton. Jour. Agr. Research [U. S.], 28 (1924), No. 6, pp. 499–513.
(22) The effect of soluble salts on the physical properties of soils. R. O. E. Davis. U. S. Dept. Agr., Bur. Soils Bul. 82. 1912.
(23) The formation of pans in soil. C. G. T. Morison. Faraday Soc. Trans., 17 (1922), No. 2, pp. 321–324.
(24) A critical pH for the formation of hardpan in acid clay soils. J. R. Skeen. Soil Sci., 22 (1925), No. 4, pp. 307–311.
(25) Relation of inorganic soil colloids to plowsole in citrus groves in southern California. C. A. Jensen. Jour. Agr. Research [U. S.], 15 (1918), No. 9, pp. 505—519.
(26) The influence of water on soil granulation. G. J. Bouyoucos. Soil Sci., 18 (1924), No. 2, pp. 103–109.
(27) Tests for subgrade soils. A. T. Goldbeck and F. H. Jackson. U. S. Dept. Agr., Public Roads, 4 (1921), No. 3, pp. 15–21.
(28) The effect of chalk on the cultivation of heavy land. E. J. Russell and B. A. Keen. Jour. Min. Agr. [London], 28 (1921), No. 5, pp. 419–422.
(29) The modulus of rupture of a soil as an index to its physical structure. R. V. Allison. Jour. Amer. Soc. Agron., 15 (1923), No. 10, pp. 409–415.
(30) Effect of lime and organic matter on impervious Kirkland upland soil. M. A. Beeson. Okla. Sta. Rpt. 1920, p. 17.
(31) The flocculation of soils. N. M. Comber. Jour. Agri. Sci. [England], 10 (1920), No. 4, pp. 425–436.
(32) An electrical method for the reducton of draft in plowing. E. M. Crowther and W. B. Haines. Jour. Agr. Sci. [England], 14 (1924), No. 2, pp. 221–231.
(33) Studies in the physical properties of soils.—I, Mechanical properties concerned in cultivation. W. B. Haines. Jour. Agr. Sci. [England], 15 (1925), No. 2, pp. 178–200.
(34) A study of the plow bottom and its action on the furrow slice. E. A. White. Jour. Agr. Research [U. S.], 12 (1918), No. 4, pp. 149–182.
(35) The sliding of metal over soil. M. L. Nichols. Agr. Engin., 6 (1925), No. 4, pp. 80–84.
(36) Calif. Sta. Rpt. 1921, p. 99.

PUBLICATIONS OF THE STATIONS (1924–25)

The following is a list of publications received by the office during the year ended June 30, 1925. Only publications of the regular station series are listed. The large and very important part of the station output published through other channels is not included. (See p. 13.)

AGRICULTURAL CHEMISTRY—AGROTECHNY

Studies with phytosterols: I, The phytosterols of the endosperm of corn. R. J. Anderson. II, The phytosterols of wheat endosperm. R. J. Anderson and F. P. Nabenhauer. III. The separation of unsaturated from saturated sterols. R. J. Anderson and F. P. Nabenhauer. IV, Reduction of sitosterol preparation of dihydrositosterol or sitostanol. R. J. Anderson and F. P. Nabenhauer. V, Sitosterol. R. J. Anderson and F. P. Nabenhauer. (N. Y. State Sta. Tech. Bul. 108, pp. 40, fig. 1. Sept., 1924.

Some chemical characteristics of soft corn. A, Bushey. (S. Dak. Sta. Bul. 210, pp. 713–718. figs. 3. June, 1924.)

Some chemical aspects of sweet corn drying. C. O. Appleman. (Md. Sta. Bul. 267, pp. 287–298 June, 1924.)

Cornstalk sirup investigations. J. J. Willaman, G. O. Burr, and F. R. Davison. (Minn. Sta. Bul. 207, pp. 58, figs. 22. Mar., 1924.)

The Hawaiian tree fern as a commercial source of starch. J. C. Ripperton. (Hawaii Sta. Bul. 53, pp. 16, pls. 7, figs. 2. July, 1924.)

Olive pickling in Mediterranean countries. W. V. Cruess. (Calif. Sta. Circ. 278, pp. 33, figs. 19. Sept., 1924.)

The preparation and refining of olive oil in southern Europe. W. V. Cruess. (Calif. Sta. Circ. 279, pp. 43, figs. 24. Oct., 1924.)

Chemical studies of the combined lead arsenate and lime-sulfur spray. R. W. Thatcher and L. R. Streeter. (N. Y. State Sta. Bul. 521, pp. 20. Aug., 1924.)

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. (Mass. Sta. Met. Buls. 426–437, pp. 4 each. June, 1924–May, 1925.)

Climatological data for Wyoming. F. E. Hepner. (Wyo. sta. Bul. 139, pp. 63–160, pls. 2, figs. 11. June, 1924.)

SOILS—FERTILIZERS

Alkali soils in Montana. E. Burke and R. M. Pinckney. (Mont. Sta. Bul. 172, pp. 20, fig. 1. Jan., 1925.)

A progress report of alkali land reclamation investigations in eastern Oregon. W. W Johnston and W. L. Powers. (Oreg. Sta. Bul. 210, pp. 27, figs. 13. Oct., 1924.)

Treatment of black alkali with gypsum. C. N. Catlin and A. E. Vinson. (Ariz. Sta. Bul. 102, pp. 291–337, pl. 1, figs. 21. Mar., 1925.)

Results of soil fertilty investigations, 1913–1922 [North Vernon Experiment Field]. C. Juengst. (Ind. Sta. [Leaflet], pp. 4. 1923.)

Results of soil fertility investigations, 1906–1922 [Scottsburg Experiment Field]. A. G. Mace. (Ind. Sta. [Leaflet], pp. 4. 1923.)

Results of soil fertility investigations, 1917–1922 [Francisco Experiment Field]. A. T. Wiancko and W. G. Volkmann. (Ind. Sta. [Leaflet], pp. 4. 1924.)

Results of soil fertility investigations, 1913–1922 [Worthington Experiment Field]. A. T. Wiancko and F. Negele. (Ind. Sta. [Leaflet], pp. 4. 1924.)

The maintenance of soil fertility.—Thirty years' work with manure and fertilizers. C. E. Thorne. (Ohio Sta. Bul. 381, pp. 243–354, figs. 10. June, 1924.)

The results of some fertility experiments on Oklahoma soils. H. F. Murphy. (Okla. Sta. Bul. 155, pp. 34, fig. 1.)

The fertility of Washington soils. F. J. Sievers and H. F. Holtz. (Wash. Col. Sta. Bul. 189, pp. 45, figs. 14. Dec., 1924.)

Maintaining the productivity of irrigated land. D. W. Pittman. (Utah Sta. Bul. 188, pp. 24, figs. 8. June, 1924.)

Replaceable bases in soils. W. P. Kelley and S. M. Brown. (Calif. Sta. Tech. Paper 15, pp. 39. Sept., 1924.)

The toxicity, movement, and accumulation of nitrates and other salts occurring in arid soils. C. E. Craig. (N. Mex. Sta. Bul. 142, pp. 65. Apr. 1924.)

The availability of phosphorus in calcareous and noncalcareous soils. J. W. Ames and C. J. Schollenberger. (Ohio Sta. Bul. 380, pp, 213–242. June, 1924.)

Soil potassium as affected by fertilizer treatment and cropping. J. W. Ames and R. H. Simon. (Ohio Sta. Bul. 379, pp. 183–212, fig. 1. June, 1924.)

Effect of cropping upon the active potash of the soil. G. S. Fraps. (Tex. Sta. Bul. 325. pp. 18, fig. 1. Sept., 1924.)

The moisture equivalent as influenced by the amount of soil used in its determination. F. J. Veihmeyer, O. W. Israelson, and J. P. Conrad. (Calif. Sta. Tech. Paper 16, pp. 61, pls. 2, figs. 9. Sept., 1924.)

A study of the biological activities in certain acid soils. W. V. Halverson. (Oreg. Sta. Bul. 211, pp. 26, figs. 5. Feb., 1925.)

Experiments with subsoiling, deep tilling, and subsoil dynamiting. R. S. Smith. (Ill. Sta. Bul. 258, pp. 153–170, figs. 6. Feb., 1925.)

The principles of summer fallow tillage. M. A. McCall and H. M. Wanser. (Wash. Col. Sta. Bul. 183, pp. 77, figs. 5. Oct., 1924.)

Saving soil by use of mangum terraces. E. W. Lehmann and F. P. Hanson. (Ill. Sta. Circ. 290, pp. 19, figs. 18. July, 1924.)

Hancock County Soils. R. S. Smith, E. E. De Turk, F. C. Bauer, and L. H. Smith. (Ill. Sta. Soil Rpt. 27, pp. 62, pls. 2, figs. 9. May, 1924.)

Mason County Soils. R S. Smith, E. E. De Turk, F. C. Bauer, and L. H. Smith. (Ill. Sta Soil Rpt. 28, pp. 62, pls. 2. figs. 9. June, 1924.)

Soil survey of Iowa.—Mills County. W. H. Stevenson, P. E. Brown, et. al. (Iowa Sta. Soil Survey Rpt. 33, pp. 63, pl. 1, figs. 13. Mar., 1924.)

Soil Survey of Iowa.—Boone County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 34, pp. 70, pl. 1, figs. 13. Apr., 1924.)

Soil survey of Iowa.—Dubuque County. W. H. Stevenson, P. E. Brown, et al. (Iowa Sta. Soil Survey Rpt. 35, pp. 72, pls. 2, figs. 14. Sept., 1924.)

The soils of Rutherford County. C. A. Mooers and H. H. Coryell. (Tenn. Sta. Bul. 130, pp. 27, figs. 6, map 1. June, 1924.)

The soils of Brazos, Camp, Ellis, and Washington Counties. G. S. Fraps. (Tex. Sta. Bul. 316, pp. 88. figs. 6. Feb., 1924.)

The chemical composition of the soils of the Bernardsville area in New Jersey. A. W. Blair and A. L. Prince. (N. J. Stas. Bul. 406, pp. 16, figs. 2. Nov., 1924.)

The chemical composition of the soils of the Chatworth area in New Jersey. A. W. Blair and A. L. Prince. (N. J. Stas. Bul. 414, pp. 15, figs. 2. Apr., 1925.)

Chemical analyses and fertility of West Virginia Soils. O. C. Bryan and E. P. Deatrick. (W. Va. Sta. Bul. 184, pp. 27, fig. 1. July, 1924.)

The results of fertilizer experiments, 1922–1923. M. Nelson and W. H. Sachs. (Ark. Sta. Bul. 192, pp. 12, figs. 2. June, 1924.)

Fifteen years of field experiments with manure, fertilizers, and lime on Sassafras silt loam soil. G. L. Schuster. (Del. Sta. Bul. 137, pp. 43, fig. 1. June, 1924.)

Economic returns from fifteen years results with manure, fertilizers, and lime on Sassafras silt loam soil. G. L. Schuster. (Del. Sta. Bul. 138, pp. 47, figs. 21. Aug., 1924.)

Fertilizers, what they are and how to use them. M. M. McCool and C. E. Millar. (Mich. Sta. Spec. Bul. 133, pp. 26, figs. 24. June, 1924.)

The use of fertilizers on Iowa soils. W. H. Stevenson and P. E. Brown. (Iowa Sta. Circ. 97, pp. 16, fig. 1. Mar., 1925.)

What is the value of a ton of stable manure? A. G. McCall and T. H. White. (Md. Sta. Bul. 266, pp. 259-286, figs. 4. May, 1924.)

Lime and its relation to crop production in Virginia. T. B. Hutcheson and T. K. Wolfe. (Va. Sta. Bul. 237, pp. 20, figs. 5. Nov., 1924.)

Gypsum and sulfur as fertilizers for legumes. J. L. St. John and J. R. Noller. (Wash. Col. Sta. Pop. Bul. 128, pp. 11. June, 1924.)

Changes in the composition and cost of fertilizers in New York from 1914 to 1924. L. L. Van Slyke. (N. Y. State Sta. Bul. 525, pp. 19. Dec., 1924.)

BOTANY—PLANT NUTRITION

Studies on the Coccaceae.—I, Previous taxonomic studies concerning the genera of the Coccaceae. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 99, pp. 44. June, 1924.)

Studies on the Coccaceae.—II, A study of the general characters of the Micrococci. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 100, pp. 83, fig. 1. June, 1924.)

Studies on the Coccaceae.—III, The nitrogen metabolism of the Micrococci. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 101, pp. 47. June, 1924.)

Studies on the Coccaceae.—IV, The classification of the genus Micrococcus Cohn. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 102, pp. 46. June, 1924.)

Studies on the Coccaceae.—V, Serological studies of the Micrococci. G. J. Hucker. (N. Y. State Sta. Tech. Bul. 103, pp. 19. June, 1924.)

A study of the conductive tissues in shoots of the Bartlett pear and the relationship of food movement to dominance of the apical buds. F. E. Gardner. (Calif. Sta. Tech. Paper 20, pp. 26, pls. 8. Apr., 1925.)

Studies on the effects of air temperature and relative humidity on the transpiration of *Pinus strobus*. E. J. Dole. (Vt. Sta. Bul. 238, pp. 39, pls. 2, figs. 10. July, 1924.)

Nutrient and toxic effects of certain ions on citrus and walnut trees with especial reference to the concentration and PH of the medium. H. S. Reed and A. R. C. Haas. (Calif. Sta. Tech. paper 17, pp. 75, pls. 3, figs. 25. Oct., 1924.)

The salt requirements of Marquis wheat in water culture for the vegetative phase of development. R. P. Hibbard and S. Gershberg. (Mich. Sta. Tech. Bul. 64, pp. 28, figs. 7. June, 1924.)

Economical use of nitrogen, phosphorus, and potassium by barley, oats, and wheat in solution cultures. F. R. Pember and F. T. McLean. (R. I. Sta. Bul. 199, pp. 53, figs. 6. Feb., 1925.)

Growth of potato plants in sand cultures treated with "six types" of nutrient solutions. E. S. Johnston. (Md. Sta. Bul. 270, pp. 53-86, figs. 8. Sept., 1924.)

The effect of the weight of the seed on the growth of the plant. D. Schmidt. (N. J. Stas. Bul. 404, pp. 19. Nov., 1924.)

GENETICS

Inheritance of Xantha seedlings in maize. H. Trajkovich. (N. Y. Cornell Sta. Mem. 82, pp. 13. Dec. 1924.

Genetic relations of five factor pairs for virescent seedlings in maize. M. Demerec. (N. Y. Cornell Sta. Mem. 84, pp. 38. Dec., 1924.)

The inheritance of brown aleurone in maize. P. Kvakan. (N. Y. Cornell Sta. Mem. 83, pp. 22. Dec., 1924.)

A biometrical analysis of characters of maize and of their inheritance. T. K. Wolfe. (Va. Sta. Tech. Bul. 26, pp. 70, figs. 26. Feb., 1924.)

Statistical studies on inheritance in the tomato. C. E. Myers. (Pa. Sta. Bul. 189, pp. 31, figs. 14. Sept., 1924.)

Inheritance of characters in sheep. A. E. Darlow. (Okla. Sta. Bul. 153, pp. 15.)

Correlation studies on winter fecundity. F. A. Hays, R. Sanborn, and L. L. James. (Mass. Sta. Bul. 220, pp. 43-53. Nov., 1924.)

High fecundity in Leghorns as an inherited character. G. W. Hervey. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 6, pp. 4, fig. 1. Mar., 1925.)

FIELD CROPS

Alfalfa yields, cultural practices, and production costs as influenced by the soil formation in New Jersey. G. W. Musgrave and A. G. Miller. (N. J. Stas. Bul. 408, pp. 31, figs. 11. Mar., 1925.)

Wisconsin's opportunity with alfalfa. R. A. Moore and L. F. Graber. (Wis. Sta. Bul. 374, pp. 32, figs. 66. Mar., 1925.)

Reaction of barley varieties to *Helminthosporium sativum*.—I, Varietal resistance. II, Inheritance studies in a cross between Lion and Manchuria. H. K. Hayes, E. C. Stakman, F. Griffee, and J. J. Christensen. (Minn. Sta. Tech. Bul. 21, pp. 47, figs. 10. July, 1923.)

Varietal trials with barley in North Dakota. T. E. Stoa. (N. Dak. Sta. Bul. 184, pp. 46, figs. 9. Oct., 1924.)

Corn in Connecticut. D. F. Jones, W. L. Slate, jr., and B. A. Brown. (Conn. State Sta. Bul. 259, pp. 381–470, figs. 67. July, 1924.)

Corn in Connecticut. D. F. Jones, W. L. Slate, jr., and B. A. Brown. (Conn. Storrs Sta. Bul. 124, pp. 309–396, figs. 83. June, 1924.)

Corn and soybeans. W. C. Etheridge and C. A. Helm. (Mo. Sta. Bul. 220, pp. 23, figs. 5. Sept., 1924.)

The cultivation of corn.—Weed control vs. moisture conservation. D. C. Wimer and M. B. Harland. (Ill. Sta. Bul. 259, pp. 173–196, figs. 8. Mar., 1925.)

A program of corn improvement. C. M. Woodworth. (Ill. Sta. Circ. 284, pp. 24, figs. 12. July, 1924.)

Corn growers face worst seed shortage in years. J. C. Hackleman. (Ill. Sta. Circ. 292, pp. 4, figs. 4. Sept., 1924.)

Methods of corn breeding. H. K. Hayes and L. Alexander. (Minn. Sta. Bul. 210, pp. 22, figs. 6. Apr., 1924.)

Corn selection for exhibit purposes. C. A. Helm. (Mo. Sta. Circ. 126, pp. 7, figs. 8. Aug., 1924.)

Big scale corn raising in Montana. H. E. Selby. (Mont. Sta. Bul. 171, pp. 46, figs. 14. Jan., 1925.)

Cultural methods for corn and grain sorghums on Oklahoma soils. H. F. Murphy. (Okla. Sta. Bul. 150, pp. 7. Jan., 1925.)

The effects of fertilizers and hybridization on maturity and yield of corn. T. B. Hutcheson and T. K. Wolfe. (Va. Sta. Tech. Bul. 27, pp. 20, figs. 3. Apr., 1924.)

Results of fertilizer experiments with cotton, 1924. M. Nelson and W. H. Sachs. (Ark. Sta. Bul. 195, pp. 12, figs. 3. Apr., 1925.)

Cotton experiments, 1924.—Varieties and fertilizers. J. F. O'Kelly and R. Cowart. (Miss. Sta. Bul. 226, pp. 12, fig. 1. Dec., 1924.)

Delfos cotton. (Miss. Sta. Circ. 52, pp. 5. June, 1924.)

Fertilizer tests with cotton in North Mississippi, Holly Springs Branch Experiment Station. (Miss. Sta. Circ. 55, pp. 4. Dec., 1924.)
Cotton experiments, South Mississippi Branch Experiment Station. E. B. Ferris. (Miss. Sta. Circ. 56, pp. 8. Dec., 1924.)
Report on southeast Missouri cotton experiment fields, 1924. B. M. King. (Mo. Sta. Circ. 132, pp. 4. Feb., 1925.)
Cotton variety tests in Oklahoma. G. Briggs. (Okla. Sta. Bul. 154, pp. 12.)
Cotton variety experiments at the main station, 1912 to 1922. B. Youngblood. (Tex. Sta. Bul. 321, pp. 22. May, 1924.)
A study of wilt resistance in flax. H. D. Barker. (Minn. Sta. Tech. Bul. 20, pp. 42, pls. 14. Nov., 1923.)
Flax in Oregon. G. R. Hyslop. (Oreg. Sta. Circ. 60, pp. 10. Apr., 1925.)
Growing orchard grass in south Missouri. C. A. Helm. (Mo. Sta. Circ. 130, pp. 8, figs. 5. Nov., 1924.)
Wyoming forage plants and their chemical composition—studies No. 6. A. T. Cundy. (Wyo. Sta. Bul. 137, pp. 16, figs. 5. June, 1924.)
Iowa farmers test new oat varieties. H. D. Hughes and J. L. Robinson. (Iowa Sta. Bul. 227, pp. 313–342, figs. 14. Mar., 1925.)
Fulghum oats for Missouri. L. J. Stadler. (Mo. Sta. Bul. 229, pp. 19, figs. 8. Jan., 1925.)
Results of experiments with oats in New York. H. H. Love and W. T. Craig. (N. Y. Cornell Sta. Bul. 436, pp. 24, figs. 8. Jan., 1925.)
Some tentative statements concerning Fowlds hulless oats. A. N. Hume. (S. Dak. Sta. Bul. 205, pp. 613–627, figs. 2. Mar., 1924.)
The pasture problem in Iowa. W. H. Stevenson, L. W. Forman, and P. E. Brown. (Iowa Sta. Circ. 89, pp. 15, figs. 2. May, 1924.)
Irrigated pastures. D. Hansen. (Mont. Sta. Bul. 166, pp. 26, figs. 4. Sept., 1924.)
Producing seed peas in Montana. C. McKee. (Mont. Sta. Circ. 128, pp. 24, figs. 5. Apr., 1925.)
Spacing of potato hills. B. A. Brown. (Conn. Storrs Sta. Bul. 119, pp. 141–151. Apr., 1924.)
Potato growing in Kentucky. J. S. Gardner and C. W. Mathews. (Ky. Sta. Circ. 34, pp. 23–58, figs. 20. June, 1924.)
Potato sprouts as an index of seed value. C. O. Appleman. (Md. Sta. Bul. 265, pp. 239–258, figs. 10. May, 1924.)
Potato investigations at the North Central Experiment Station, 1914–1923. O. I. Bergh. (Minn. Sta. Bul. 212, pp. 58, figs. 30. May, 1924.)
Potato breeding methods. F. A. Krantz. (Minn. Sta. Tech. Bul. 25, pp. 32, figs. 5. Dec., 1924.)
Experiments with potatoes.—I, Dusting vs. spraying. F. C. Stewart and P. J. Parrott. II, Row competition and border effect. F. C. Stewart. (N. Y. State Sta. Bul. 518, pp. 36. July, 1924.)
Sprays outrank dusts for potatoes. F. C. Stewart and P. J. Parrott. (N. Y. State Sta. Bul. 518, pop. ed., pp. 4, fig. 1. Feb., 1925.)
Growing disease-free seed potatoes. F. C. Stewart. (N. Y. State Sta. Bul. 522, pop. ed., pp. 4, fig. 1. Feb., 1925.)
The influence of plot size and replication on experimental error in field trials with potatoes. K. C. Westover. (W. Va. Sta. Bul. 189, pp. 32, figs. 11. Nov., 1924.)
Results of rice experiments at Cortena, 1923, and progress in experiments in water grass control at the Biggs Rice Field Station, 1922–23. C. F. Dunshee and J. W. Jones. (Calif. Sta. Bul. 375, pp. 38, figs. 6. Feb., 1924.)
Soybeans.—A good legume crop—borrowed from the Orient. R. A. Moore, E. J. Delwiche, and G. M. Briggs. (Wis. Sta. Bul. 375, pp. 32, figs. 14. Apr., 1925.)
Sugar beets in Louisiana. A. F. Kidder and C. E. Coates. (La. Stas. Bul. 192, pp. 23. Dec., 1924.)
Tests with sugar beets. E. E. Down. (Mich. Sta. Circ. 66, pp. 8, figs. 2. Feb., 1925.)
Sweet potato experiments, South Mississippi Branch Experiment Station. W. S. Anderson and F. B. Richardson. (Miss. Sta. Circ. 57, pp. 7. Dec., 1924.)
Sweet potato studies in New Jersey. L. G. Schermerhorn. (N. J. Stas. Bul. 398, pp. 19, figs. 11. Aug., 1924.)
Dark tobacco.—Fertility experiments at the Clarksville Station—results from a ten-year period, 1913–1922. C. A. Mooers and R. H. Milton. (Tenn. Sta. Bul. 129, pp. 23, figs. 8. June, 1924.)
Varietal experiments with wheat, oats, barley, rye, and buckwheat (a preliminary report). R. J. Garber, K. S. Quisenberry, T. E. Odland, and T. C. McIlvaine. (W. Va. Sta. Bul. 192, pp. 26, figs. 4. Dec., 1924.)
Spring small grains. T. A. Kiesselbach and W. E. Lyness. (Nebr. Sta. Bul. 201, pp. 45, figs. 14. Nov., 1924.)
Spring crops for eastern Oregon. D. E. Stephens, R. Withycombe, and O. Shattuck. (Oreg. Sta. Bul. 204, pp 36, figs. 14. May, 1924.)
Crop yields on soil experiment fields in Iowa. W. H. Stevenson, P. E. Brown, L. W. Forman, et al. (Iowa Sta. Bul. 221, pp. 73–104, figs. 2. July, 1924.)
Summer annuals for hay in Connecticut. B. A. Brown. (Conn. Storrs Sta. Bul. 120, pp. 153–172, figs. 2. May, 1924.)
Green manure and soil building crops for Arizona. G. E. Thompson, R. S. Harkins, and S. P. Clark. (Ariz. Sta. Bul. 104, pp. 359–379, pl. 1, figs. 7. Apr., 1925.)
Green manuring crops for soil improvement. A. G. McCall. (Md. Sta. Bul. 268, pp. 14, figs. 2. July, 1924.)
Experiments in crop rotation and fertilization. R. C. Wiggans. (N. Y. Cornell Sta. Bul. 434, pp. 56, figs. 5. Nov., 1924.)
Dry-farm crop rotation experiments at Moro, Oreg. D. E. Stevens. (Oreg. Sta. Bul. 209, pp. 45, figs. 2. Sept., 1924.)
The yield and mineral content of crop plants as influenced by those preceding. P. S. Burgess. (R. I. Sta. Bul. 198, pp. 25. June, 1924.)
Weeds of New Jersey. J. G. Fiske. (N. J. Stas. Circ. 161, pp. 36, figs. 25. Mar., 1924.)
Weeds of cranberry bogs. C. S. Beckwith and J. G. Fiske. (N. J. Stas. Circ. 171, pp. 23, figs. 23. Jan., 1925.)
Perennial sow thistle: Growth and reproduction. O. A. Stevens. (N. Dak. Sta. Bul. 181, pp. 44, figs. 28. Aug., 1924.)
Weeds and their control. E. J. Petry. (S. Dak. Sta. Bul. 211, pp. 82, figs. 46. Dec., 1924.)
Ridding the land of wild morning glory. G. Stewart and D. W. Pittman. (Utah Sta. Bul. 189, pp. 30, figs. 10. Aug., 1924.)

HORTICULTURE

FRUITS

An experiment in breeding apples.—II. R. Wellington. (N. Y. State Sta. Tech. Bul. 106, pp. 149. Aug., 1924.)
Varieties of tree fruits for Iowa planting.—Part I, Apples. H. L. Lantz. (Iowa Sta. Circ. 92, pp. 32, figs. 11. June, 1924.)
Fertilization of apple orchards in Maine. K. Sax. (Me. Sta. Bul. 322, pp. 8, pl. 1. Jan., 1925.)
Twenty-five years of fertilizers in a New York apple orchard. U. P. Hedrick and H. B. Tukey. (N. Y. State Sta. Bul. 516, pp. 28, fig. 1. Feb., 1924.)
Do fertilizers pay in New York apple orchards? (N. Y. State Sta. Bul. 516, pop. ed., pp. 4, fig. 1. Aug., 1924.)
Fertility in the apple orchard. R. D. Anthony and J. H. Waring. (Pa. Sta. Bul. 192, pp. 15, figs. 5. Feb., 1925.)
Grafting in the apple orchard. H. A. Cardinell and F. C. Bradford. (Mich. Sta. Spec. Bul. 142, pp. 39, figs. 29. Jan., 1925.)
Changes produced in apple trees by various types of pruning. H. D. Hooker, jr. (Mo. Sta. Research Bul. 72, pp. 11, fig. 1. Dec., 1924.)
Some effects of freezing on mature fruits of the apple. D. B. Carrick. (N. Y. Cornell Sta. Mem. 81, pp. 54, pls. 7. Dec., 1924.)
The relation of low temperatures to root injury of the apple. R. F. Howard. (Nebr. Sta. Bul. 199, pp. 32, figs. 4. Apr., 1924.)
Experiments on resistance of apple roots to low temperatures. G. F. Potter. (N. H. Sta. Tech. Bul. 27, pp. 34, figs. 2. June, 1924.)

Liquid lime sulphur versus sulphur dust for apple spraying. F. P. Cullinan and C. E. Baker. (Ind. Sta. Bul. 283, pp. 22, figs. 9. July, 1924.)
Spray calendar for apples and quinces. (N. J. Stas. Circ. 173, pp. 4, fig. 1. Feb., 1925.)
Studies relating to the harvesting and storage of apples and pears. H. Hartman. (Oreg. Sta. Bul. 206, pp. 32, figs. 2. July, 1924.)
Apple storage investigations. Fourth progress report. I, Jonathan-spot and soft-scald. II, Apple-scald and internal breakdown. H. H. Plagge and T. J. Maney. (Iowa Sta. Bul. 222, pp. 63, figs. 16. Oct., 1924.)
Air-cooled storage for apples. R. E. Marshall. (Mich. Sta. Spec. Bul. 146, pp. 54, figs. 32. Apr., 1925.)
The Guatemalan avocado in Hawaii. W. T. Pope. (Hawaii Sta. Bul. 51, pp. 24, pls. 10. Aug., 1924.)
Pollination of the sweet cherry. W. P. Tufts and G. L. Philp. (Calif. Sta. Bul. 385, pp. 28, figs. 11. Mar., 1925.)
How to prune the young cherry tree. R. H. Roberts. (Wis. Sta. Bul. 370, pp. 16, figs. 14. Oct., 1924.)
Preliminary studies relating to harvesting and canning of sweet cherries. H. Hartman. (Oreg. Sta. Circ. 61, pp. 22, figs. 7. May, 1925.)
Fertilizing citrus trees in California. R. W. Hodgson. (Calif. Sta. Circ. 283, pp. 24. Apr., 1925.)
The dry-mix spray for peaches. F. J. Schneiderhan and R. H. Hurt. (Va. Sta. Bul. 239, pp. 16, figs. 3. Jan., 1925.)
Spray calendar for peaches. (N. J. Stas. Circ. 174, pp. 4, figs. 3. Feb., 1925.)
The cold storage of pears. E. L. Overholser and L. P. Latimer. (Calif. Sta. Bul. 377, pp. 56, figs. 12. Apr., 1924.)
Drying prunes in Oregon. E. H. Wiegand. (Oreg. Sta. Bul. 205, pp. 26, figs. 24. May, 1924.)
Grape experiments at the South Mississippi Experiment Station. W. S. Anderson. (Miss. Sta. Circ. 59, pp. 6. Dec., 1924.)
The behaviour of American grapes grafted on vigorous stocks. F. E. Gladwin. (N. Y. State Sta. Bul. 508, pp. 54, pls. 6. Jan., 1924.)
Improving grapes by grafting. (N. Y. State Sta. Bul. 508, pop. ed., pp. 4, figs. 2. Aug., 1924.)
The grafting of American grapes. F. E. Gladwin. (N. Y. State Sta. Bul. 520, pp. 18, pls. 6. July, 1924.)
Head, cane, and cordon pruning of vines. F. T. Bioletti and H. E. Jacob. (Calif. Sta. Circ. 277, pp. 32, figs. 23. Aug., 1924.)
Profitable pruning of the Concord grape. N. L. Partridge. (Mich. Sta. Spec. Bul. 141, pp. 12, figs. 10. Jan., 1925.)
A correlation between color of grape leaves at time of foliation and fruit color. F. E. Gladwin. (N. Y. State Sta. Tech. Bul. 107, pp. 8. Sept., 1924.)
Phylloxera resistant vineyards. L. O. Bonnet. (Calif. Sta. Circ. 288, pp. 24, figs. 14. May, 1925.)
Spraying schedule for grapes. C. R. Phipps. (Mo. Fruit Sta. Circ. 22, pp. 4. fig. 1. Mar., 1924.)
Blackberry, raspberry, and dewberry culture. H. G. Swartwout. (Mo. Sta. Bul. 231, pp, 24, figs. 11. Mar., 1925.)
Winter pruning the black raspberry. S. Johnston. (Mich. Sta. Spec. Bul. 143, pp. 22, figs. 6. Mar., 1925.)
Blueberry culture. C. S. Beckwith. (N. J. Stas. Circ. 170, pp. 8, figs. 6. Sept., 1924.)
Gooseberries and currants. H. G. Swartwout. (Mo. Sta. Bul. 232, pp. 12, figs. 6. Apr., 1925.)
A taxonomic review of currants and gooseberries. A. Berger. (N. Y. State Sta. Tech. Bul. 109, pp. 118, pls. 8. Dec., 1924.)
Strawberries and farm profits in western Kentucky. J. B. Hutson. (Ky. Sta. Bul. 255, pp. 131–171, figs. 11. Dec., 1924.)
Strawberry culture in Missouri. T. J. Talbert. (Mo. Sta. Circ. 123, pp. 12, figs. 6. June, 1924.)
Fruit culture in North Dakota. A. F. Yeager. (N. Dak. Sta. Bul. 188, pp. 23, figs. 25. Feb., 1925.)
Explanatory note. E. B. Merrill. Fruit bud differentiation in deciduous fruits. W. P. Tufts and E. B. Morrow. (Hilgardia [California Sta.], vol. 1, No. 1, pp. 14, pls. 12. May, 1925.)
Pruning bearing deciduous fruit trees. W. P. Tufts. (Calif. Sta. Bul. 386, pp. 47, figs. 21. Apr., 1925.)
Some orchard conditions affected by arsenicals, marls, and other factors. W. P. Headden. (Colo. Sta. Bul. 294, pp. 31, pls. 10. Dec., 1924.)
Spraying Missouri fruits. T. J. Talbert. (Mo. Sta. Bul. 216, pp. 32, figs. 14. July, 1924.)
Spraying calendar. W. C. Dutton, R. H. Pettit, C. W. Bennett, and H. A. Cardinell. (Mich. Sta. Spec. Bul. 140, pp. 29, figs. 11. Jan., 1925.)
How to store and germinate fruit seed. (N. Y. State Sta. Bul. 509, pop. ed., pp. 4, fig. 1. Aug., 1924.)
Coffee varieties in Porto Rico. T. B. McClelland. (Porto Rico Sta. Bul. 30, pp. 27, pls. 11. June, 1924.)

NUTS

The almond in California. R. H. Taylor and G. L. Philp. (Calif. Sta. Circ. 284, pp. 57, figs. 19. Apr., 1924.)
Filberts.—I, Growing filberts in Oregon; II, Experimental data on filbert pollination. C. E. Schuster. (Oreg. Sta. Bul. 208, pp. 39, figs. 17. Aug., 1924.)
The development of pecan buds and the quantitative production of pollen. J. G. Woodroof. (Ga. Sta. Bul. 144, pp. 133–161, figs. 20. June, 1924.)
Preliminary pecan experiments. F. Garcia and A. B. Fite. (N. Mex. Sta. Bul. 145, pp. 18, figs. 6. Jan., 1925.)
Walnut culture in California. L. D. Batchelor. (Calif. Sta. Bul. 379, pp. 91, figs. 34. June, 1924.)

VEGETABLES

Physical and chemical factors in the growth of asparagus. E. B. Working. (Ariz. Sta. Tech. Bul. 5, pp. 85–124, figs. 14. Apr., 1925.)
Growing and handling asparagus crowns. H. A. Jones and W. W. Robbins. (Calif. Sta. Bul. 381, pp. 34, figs. 15. Dec., 1924.)
Factors influencing the rate of germination of the seed of *Asparagus officinalis*. H. A. Borthwick. (Calif. Sta. Tech. Paper 18, pp. 17, figs. 2. Mar., 1925.)
Edible canna in Hawaii. H. L. Chung and J. C. Ripperton. (Hawaii Sta. Bul. 54, pp. 16, pls. 2, figs. 4. July, 1924.)
Dusting and spraying cantaloupes. R. A. Jehle and S. F. Potts. (Md. Sta. Bul. 263, pp. 169–180, figs. 6. Apr., 1924.)
Truck crop investigations.—Spraying and dusting cantaloupes. H. H. Zimmerley, R. J. Davis, and H. Spencer. (Va. Truck. Sta. Bul. 45, pp. 293-313, figs. 2. Oct., 1923.)
Premature seeding of celery. C. C. Starring. (Mont. Sta. Bul. 168, pp. 16, fig. 1. Nov. 1924,
Truck crop investigations.—Dusting and spraying eggplants. H. Spencer, H. H. Zimmerley, and R. J. Davis. (Va. Truck Sta. Bul. 47, pp. 329-347, fig. 1. Apr., 1924.)
The onion industry in Pleasant Valley, Iowa. A. T. Erwin and W. L. Harter. (Iowa Sta. Bul. 225, pp. 257–286, figs. 16. Jan., 1925.)
Variations in varieties of canning peas. F. H. Hall. (N. Y. State Sta. Bul. 526, pp. 20. Dec., 1924.)
Canning peas. F. H. Hall. (N. Y. State Sta. Bul 526, pop. ed., pp. 4, fig. 1. Feb., 1925.)
Inoculation increases yield and quality of peas for canning. A. L. Whiting, E. B. Fred, and J. W. Stevens. (Wis. Sta. Bul. 372, pp. 24, figs. 20. Jan., 1925.)
Truck crop investigations.—Spinach fertilizers. H. H. Zimmerley. (Va. Truck Sta. Bul. 44, pp. 279–291. July, 1923.)
Growing tomatoes for the canning factory. H. D. Brown. (Ind. Sta. Bul. 288, pp. 27, figs. 19. Nov., 1924.)
Tomato experiments at the South Mississippi Experiment Station. W. S. Anderson and F. B. Richardson. (Miss. Sta. Circ. 58, pp. 7. Dec., 1924.)
Nitrate of soda in the nutrition of the tomato. P. Work. (N. Y. Cornell Sta. Mem. 75, pp. 86, figs. 38. June, 1924.)
Truck crop investigations.—Dusting and spraying tomatoes. R. J. Davis, H. Spencer, and H. H. Zimmerley. (Va. Truck Sta. Bul. 46, pp. 315–327, figs. 3. Jan., 1924.)

Report on survey of canning tomato industry, with suggestions for improvement. F. L. Yaw. (Calif. Sta. Circ. 280, pp. 30, figs. 12. Nov.,1924.)
Studies in the transplanting of vegetable plants. W. E. Loomis. (N. Y. Cornell Sta. Mem. 87, pp. 63, figs. 21. Feb., 1925.)
Vegetable varieties for North Dakota. A. F. Yeager. (N. Dak. Sta. Bul. 187, pp. 27, figs. 9. Feb., 1925.)
Manures and fertilizers for truck crops. J. H. Gourley and R. Magruder. (Ohio Sta. Bul 37, pp. 117-152, figs. 4. June, 1924.)

ORNAMENTALS

Flowers every day in the year. N. F. Hanson. (S. Dak. Sta. Bul. 208, pp. 675-690, figs. 15. May, 1924.)
Roses in the garden. C. H. Conners. (N. J. Stas. Circ. 172, pp. 27, figs. 14. Nov., 1924.)
Some natural violet hybrids of North America. E. Brainerd and G. P. Burns. (Vt. Sta. Bul. 239, pp. 205, figs. 83. July, 1924.)
Hedges for Florida. H. Mowry. (Fla. Sta. Bul. 172, pp. 20, figs. 13. July, 1923.)
The pruning of shrubs. M. A. Blake. (N. J. Stas. Circ. 176, pp. 8, figs. 4. Apr., 1925.)

FORESTRY

The growth, returns, and uses of planted cottonwood in Iowa. G. B. MacDonald. (Iowa Sta. Bul. 223, pp. 167-201, figs. 10. Nov., 1924.)
Growth of the eucalyptus in California plantations. W. Metcalf. (Calif. Sta. Bul. 380, pp. 61, figs. 27. Nov., 1924.)
The Rainbow Forest Plantations.—Guide to experimental plots and report of progress, 1924. H. W. Hicock. (Conn. State Sta. Bul. 262, pp. 101–135, pls. 9. Dec., 1924.)
Christmas tree plantations. A. K. Chittenden. (Mich. Sta. Spec. Bul. 145, pp. 9, figs. 3. Mar., 1925.)

PLANT DISEASES

DISEASES OF FIELD CROPS

Corn root, stalk, and ear rot diseases, and their control thru seed selection and breeding. J. R. Holbert, W. L. Burlison, B. Koehler, C. M. Woodworth, and G. H. Dungan. (Ill. Sta. Bul. 255, pp. 235–478, pls. 6, figs. 86. Aug., 1924.)
Corn root, stalk, and ear rot diseases, and their control thru seed selection and breeding. J. R. Holbert. W. L. Burlison. B. Koehler, C. M. Woodworth, and G. H. Dungan. (Ill. Sta. Bul. 255, abridged, pp. 99. pls. 6, figs. 40. May, 1925.)
A bacterial disease of foxtail (*Chaetochloa lutescens*.) H. R. Rosen. (Ark. Sta. Bul. 193, pp. 66, pls. 7. Aug., 1924.)
Potato diseases. (Ohio Sta. Bul. 374, pp. 30, figs 18. Mar., 1924.)
The respiration of potato tubers in relation to the occurrence of blackheart. J. P. Bennett and E. T. Bartholomew. (Calif. Sta. Tech. Paper 14, pp. 35, pls. 3, fig. 1. Jan., 1924.)
The importance and natural spread of potato degeneration diseases. D. Folsom and E. S. Schultz. (Me. Sta. Bul. 316, pp. 28, pls. 4. Jan., 1924.)
Further studies on the effect of environment on potato degeneration diseases. R. W. Goss and G. L. Peltier. (Nebr. Sta. Research Bul. 29, pp. 32, pls. 7. Jan., 1925.)
Potato leaf roll in Indiana. M. W. Gardner and J. B. Kendrick. (Ind. Sta. Bul. 284, pp. 23, figs. 8. July, 1924.)
Control of leaf roll and mosaic in potatoes by isolating and roguing the seed plat. F. C. Stewart. (N. Y. State Sta. Bul. 522, pp. 14. Aug., 1924.)
The Rhizoctonia disease of the potato. B. F. Dana. (Wash. Col. Sta. Pop. Bul. 131, pp. 30, figs. 6. Jan., 1925.)
The spindle tuber disease: One cause of "run out" seed potatoes. H. O. Werner. (Nebr. Sta. Bul. 207, pp. 21. figs 14. Apr., 1925.)
Potato wilt and stem end rot caused by *Fusarium eumartii*. R. W. Goss. (Nebr. Sta. Research Bul. 27, pp. 83, pls. 9, figs. 4. June, 1924.)
The sugar cane disease situation in 1923 and 1924. C. W. Edgerton, W. G. Taggart, and E. C. Tims. (La. Stas. Bul. 191, pp. 44, figs. 8. Dec., 1924.)
The copper carbonate dust method of controlling bunt of wheat. L. E. Melchers and H. B. Walker. (Kans. Sta. Circ. 107, pp. 14, figs. 5. July, 1924.)
Wheat rosette and its control. H. H. McKinney, R. W. Webb, and G. H. Dungan. (Ill. Sta. Bul. 264, pp. 273–296, pl. 1, figs. 8. Apr., 1925.)
Root rots of wheat. A. W. Henry. (Minn. Sta. Tech. Bul. 22, pp. 71, pls. 12, figs. 2. Apr., 1924.)
The take-all disease of cereals and grasses caused by *Ophiobolus cariceti* (Berkeley and Broome) Saccardo. R. S. Kirby. (N. Y. Cornell Sta. Mem. 88, pp. 45, pls. 3, figs. 4. Mar., 1925.)
Phyllosticta leaf spot, fruit blotch, and canker of the apple: Its etiology and control. E. F. Guba. (Ill. Sta. Bul. 256, pp. 479–557, pls. 4, figs. 18. Feb., 1925.)

DISEASES OF FRUILS

Apple blotch control in Missouri. T. J. Talbert. (Mo. Sta. Circ. 124, pp. 8, figs. 2. June, 1924.)
Spraying early apples for blotch control. J. A. McClintock and C. D. Sherbakoff (Tenn. Sta. Bul. 132, pp. 8, figs. 2. Mar., 1925.)
The spore discharge of the apple scab fungus in Delaware. J. F. Adams. (Del. Sta. Bul. 140, pp. 16, figs. 4. Apr., 1925.)
Experiments on the control of apple scab and black rot and spray injury in 1924. W. L. Doran. (Mass. Sta. Bul. 222, pp. 10. Mar., 1925.)
Comparison of materials used in spraying and dusting for apple scab control in Pennsylvania. H. W. Thurston, jr., R. C. Walton, and F. N. Fagan. (Pa. Sta. Bul. 190, pp. 20, figs. 5. Dec., 1924.)
Monilia blossom blight (brown rot) of apricots. B. A. Rudolph. (Calif. Sta. Bul. 383, pp. 55, figs. 10. Feb., 1925.)
Cherry leaf-spot; residual effects and control. W. C. Dutton and H. M. Wells. (Mich. Sta Spec. Bul. 147, pp. 15, fig. 1. May, 1925.)
Spraying dewberries for anthracnose. W. C. Dutton. (Mich Sta. Spec. Bul. 144, pp. 13, figs. 3. Mar., 1925.)
Fig smut. E. H. Phillips, E. H. Smith, and R. E. Smith. (Calif. Sta. Bul. 387, pp. 38, figs. 15. Apr., 1925.)
Manganese chlorosis of pineapples: Its cause and control. M. O. Johnson. (Hawaii Sta. Bul. 52, pp. 38, pls. 4, figs. 5. July, 1924.)
Raspberry mosaic and blue stem. W. H. Rankin. (N. Y. State Sta. Circ. 75, pp. 4. Mar., 1924.)
Spraying experiments for pecan scab control in Mississippi in 1923. D. C. Neal, O. M. Chance, R. P. Barnhart, and E. K. Bynum. (Miss. Sta. Circ. 53, pp. 4. July, 1924.)

DISEASES OF VEGETABLES

Wire stem of cabbage. L. O. Gratz. (N. Y. Cornell Sta. Mem. 95, pp. 60, pls. 7, figs. 15. Jan., 1925.)
Celery diseases in Florida. A. C. Foster and G. W. Weber. (Fla. Sta. Bul. 173, pp. 21–78, figs. 34. Dec., 1924.)
The control of bacterial blight of celery by spraying and dusting. H. W. Dye and A. G. Newhall. (N. Y. Cornell Sta Bul. 429, pp. 30, figs. 11. June, 1924.)
The smut disease of onions. P. J. Anderson and A. V. Osmun. (Mass. Sta. Bul. 221, pp. 29, pls. 4. Dec., 1924.)
The stem rot of sweet potatoes.—Losses, sources of infection, and control. R. F. Poole. (N. J. Stas. Bul. 401, pp. 32, figs. 13. Aug., 1924.)
Tomato wilt and its control in Arkansas. J. A. Elliott. (Ark. Sta. Bul. 194, pp. 11, pls. 5, fig. 1. Sept., 1924.)
Fusarium wilt of tomato and its control by means of resistant varieties. J. W. Lesley. (Calif. Sta. Circ. 274, pp. 6, figs. 2. Jan., 1924.)

MISCELLANEOUS

Tulip blossom blight. F. L. Stevens and O. A. Plunkett. (Ill. Sta. Bul. 265, pp. 297-307, figs. 8. Apr., 1925.)
The gray bulb-rot of tulips caused by *Rhizoctonia tuliparum* (Klebh.) n. comb. H. E. Whetzel and J. M. Arthur. (N. Y. Cornell Sta. Mem. 89, pp. 18, pls. 8, figs. 6. Mar., 1925.)
Ergot and its control. W. Weniger. (N. Dak. Sta. Bul. 176, pp. 23, figs. 12. Apr., 1924.)
Oak fungus in orchard trees. A. B. Hendrickson. (Calif. Sta. Circ. 289, pp. 13, figs. 7. May, 1925.)
Rust infection of leaves in Petri dishes. G. P. Clinton and F. A. McCormick. (Conn. State Sta. Bul. 260, pp. 473-501, pls. 2. Nov., 1924.)
Fruit-rotting sclerotinias.—II, The American brown-rot fungi. W. N. Ezekiel. (Md. Sta. Bul. 271, pp. 87-142, figs. 22. Oct., 1924.)
Control equipment for the study of the relation of environment to disease. G. L. Peltier and R. W. Goss. (Nebr. Sta. Research Bul. 28, pp. 16, pls. 3, figs. 4. June, 1924.)
Protecting South Carolina from plant diseases and crop pests. J. A. Berly. (S. C. Sta. Circ. 32, pp. 32, figs. 22. Dec., 1924.)

ENTOMOLOGY

INSECTS AFFECTING FIELD CROPS

The alfalfa weevil in Nevada and its control by spraying. S. J. Snow. (Nev. Sta. Bul. 108, pp. 22, figs. 4. May, 1925.)
The clover-seed caterpillar. L P. Wehrle. (N. Y. Cornell Sta. Bul. 428, pp. 34, figs. 13. June, 1924.)
A progress report of boll weevil poisoning work at the Holly Springs Branch Experiment Station. C. T. Ames. (Miss. Sta. Circ. 54, pp. 12. Dec., 1924.)
Poisoning the boll weevil in the Piedmont section of South Carolina. C. B. Nickles. (S. C. Sta. Circ. 33, pp. 39, figs. 8. Feb., 1925.)
Cotton boll weevil control in Texas. A. B. Conner and H. J. Reinhard. (Tex. Sta. Circ. 32, pp. 14. May, 1924.)
The more important insects injurious to the sugar beet in Utah. I. M. Hawley. (Utah Sta. Circ. 54, pp. 47, figs. 33. Apr., 1925.)
Chinch bug barriers for Kansas conditions. J. W. McColloch. (Kans. Sta. Circ. 113, pp. 6, figs. 3. June, 1925.)

INSECTS AFFECTING FRUITS

Apple blister-mite and its control. L. Childs. (Oreg. Sta. Circ. 59, pp. 8, figs. 4. Feb., 1925.)
The apple trumpet leafminer (*Tischeria malifoliella* Clem.). E. W. Dunnam. (Iowa Sta. Bul. 220. pp. 49-72, figs. 6. June, 1924.)
A biological study of *Aphelinus mali* Hald., a parasite of the woolly apple aphid, *Ericsoma lanigera* Hausm. A. E. Lundie. (N. Y. Cornell Sta. Mem. 79, pp. 27, figs. 7. Aug., 1924.)
The blueberry leaf-beetle and some of its relatives. H. C. Fall and W. C. Woods. (Me. Sta. Bul. 319, pp. 81-140, pl. 1, figs. 2. Oct., 1924.)
The cherry maggots. R. H. Pettit. (Mich. Sta. Circ. 67, pp. 2, fig. 1. Mar., 1925.)
Controlling the citrus aphis (*Aphis spiraecola* Patch). J. R. Watson and A. H. Beyer. (Fla. Sta. Bul. 174, pp. 79-96, figs. 9. Mar., 1925.)
Control of the cranberry girdler by submerging in water. C. S. Beckwith. (N. J. Stas. Bul. 411, pp. 14, fig. 1. Feb., 1925.)
Comparative efficiency of dust and spray mixtures in controlling the currant aphis. P. J. Parrott and S. W. Harman. (N. Y. State Sta. Bul. 517, pp. 21, pls. 5. July, 1924.)
The control of climbing cutworms and grape flea beetles. C. R. Phipps. (Mo. Fruit Sta. Circ. 21, pp. 4, fig. 1. Feb., 1924.)
The grape leaf hoppers of bluegrass Kentucky. H. H. Jewett. (Ky. Sta. Bul. 254, pp. 85-130. Aug., 1924.)
Dusting and spraying to control grape root-worm. F. Z. Hartzell. (N. Y. State Sta. Bul. 519, pp. 29, pls. 2, figs. 2. July, 1924.)
Poison spray for grape rootworm. F. Z. Hartzell. (N. Y. State Sta. Bul. 519, pop. ed., pp. 3, pls. 2, fig. 1. Feb., 1925.)
The comparative value of carbon bisulfide and other organic compounds as soil insecticides for the control of the Japanese beetle (*Popillia japonica* Newm.). W. E. Fleming. (N. J. Stas. Bul. 410, pp. 29. Feb., 1925.)
The oriental fruit worm. B. A. Porter. (Ind. Sta. Circ. 122, pp. 8, figs. 5. May, 1925.)
A preliminary report on the oriental peach moth in New Jersey. A. Peterson and L. A. Stearns. (N. J. Stas. Circ. 175, pp. 11, figs. 7. Mar., 1925.)
Fumigation with hydrogen cyanide for control of the pear psylla. R. L. Webster. (N. Y. State Sta. Bul. 523, pp. 23, pls. 4, fig. 1. Nov., 1924.)
The strawberry weevil. W. J. Baerg. (Ark. Sta. Circ. 50, pp. 7, figs. 3. June, 1924.)
Injurious insect pests of strawberries. O. C. McBride. (Mo. Sta. Bul. 215, pp. 12, figs. 6. June, 1924.)

INSECTS AFFECTING VEGETABLES

The Mexican bean beetle. L. M. Peairs. (W. Va. Sta. Circ. 39, pp. 7, figs. 4, June, 1925.)
New insecticides for the Mexican bean beetle and other insects. S. Marcovitch. (Tenn. Sta. Bul. 131, pp. 19, figs. 7. Oct., 1924.)
The cabbage maggot: Its control in the seedbed. H. Glasgow. (N. Y. State Sta. Circ. 76, pp. 4, pls. 2. Mar., 1924.)
Melon and cucumber insects. C. J. Drake and F. A. Fenton. (Iowa Sta. Circ. 90, pp. 8, figs. 11. May, 1924.)

MISCELLANEOUS

The buckthorn aphid. E. M. Patch. (Me. Sta. Bul. 317, pp. 27-52, figs. 3. Apr., 1924.)
The biology and control of the chrysanthemum midge (*Diarthronomyia hypogaea*, F. Low). C. C. Hamilton. (Md. Sta. Bul. 269, pp. 51, figs. 9. Aug., 1924.)
The rose chafer. F. Z. Hartzell. (N. Y. State Sta. Circ. 74, pp. 4, pls. 2. Mar., 1924.)
Pale western cutworm in North Dakota. R. L. Webster and C. N. Ainslie. (N. Dak. Sta. Bul. 179, pp. 24, pls. 2, figs. 6. Apr., 1924.)
The European earwig. B. B. Fulton. (Oreg. Sta. Bul. 207, pp. 29, figs. 8. Aug., 1924.)
Observations on the clear-winged grasshopper (*Camnulla pellucida* Scudder). J. R. Parker. (Minn. Sta. Bul. 214, pp. 44, figs. 6. July, 1924.)
Control of the European red mite. C. C. Hamilton. (Md. Sta. Bul. 264, pp. 181-238, figs. 8. Apr., 1924.)
A systematic study of the Anthomyiinae of New York, with especial reference to the male and female genitalia. H. C. Huckett. (N. Y. Cornell Sta. Mem. 77, pp. 91, figs. 202. Aug., 1924.)
The Cicadellidae of the vicinity of Ithaca, N. Y., with special reference to the structure of the gonapophyses. J. L. Buys. (N. Y. Cornell Sta. Mem. 80, pp. 115, pls. 15. Dec., 1924.)
A study of the leaf-mining Diptera of North America. S. W. Frost. (N. Y. Cornell Sta. Mem. 78, pp. 228, pls. 14. Aug., 1924.)
The Lepidoptera of New York and neighboring States. W. T. M. Forbes. (N. Y. Cornell Sta. Mem. 68, pp. 729, figs. 439. June, 1923.)
A taxonomic and ecological study of the species of the subfamily Oedipodinae (*Orthoptera acrididae*) found in Utah. W. W. Henderson. (Utah Sta. Bul. 191, pp. 150, figs. 17. Sept., 1924.)
White ants (termites). R. H. Pettit. (Mich. Sta. Circ. 63, pp. 2, figs. 2. June, 1924.)
Greenhouse insects. E. I. McDaniel. (Mich. Sta. Spec. Bul. 134, pp. 75, figs. 41. June, 1924.)
Prevention of insect attack on stored grain. W. W. Mackie. (Calif. Sta. Circ. 282, pp. 8, fig. 1. Feb., 1925.)

INSECTICIDES

Factors affecting efficiency in fumigation with hydrocyanic acid. H. Knight. (Hilgardia [Calif. Sta.], vol. 1, No. 3, pp. 35-56, figs. 10. May, 1925.)
Some further facts relative to the principles underlying the making and use of nicotine dust. T. J Headlee and W. Rudolphs. (N. J. Stas. Bul. 400, pp. 44, figs. 20. Aug., 1924.)
Oil sprays.—Their preparation and use for insect control. A. L. Melander, A. Spuler, and E. L. Green. (Wash. Col. Sta. Bul. 184, pp. 21. Nov., 1924.)

BEEKEEPING

Beekeeping for beginners. H. Garman. (Ky. Sta. Circ. 35, pp. 34, figs. 11. Mar., 1925.)
Suggestions on queen rearing. H. B. Parks and A. H. Alex. (Tex. Sta. Circ. 35, pp. 19, figs. 11. Feb. 1925.)
Seasonal management for commercial apiaries. R. H. Kelty. (Mich. Sta. Spec. Bul. 135, pp. 58, figs. 30. June, 1924. Supplement, chart.)
I, Foul brood control and diseases of bees. II, Foulbrood law and revised regulations, F. L. Thomas and C. S. Rude. (Tex. Sta. Circ. 36, pp. 24, pl. 1, figs. 2. Aug., 1924.)

FOODS AND HUMAN NUTRITION

Missouri flour for Missouri breadmaking. L. E. Davis. (Mo. Sta. Bul. 227, pp. 31, figs. 28. Dec., 1924.)
Viscosity as a measure of hydration capacity of wheat flour and its relation to baking strength. P. F. Sharp and R. A. Gortner. (Minn. Sta. Tech. Bul. 19, pp. 119, figs. 14. Oct., 1923.)
Honey: Its use in the home. H. Jordan. (Ind. Sta. Circ. 121, pp. 12, figs. 3. Apr., 1925.)
The antiscorbutic value of commercially concentrated orange juice. H. Goss. (Hilgardia [Calif. Sta.], vol. 1, No. 2, pp. 15-34, figs. 14. May, 1925).
Home canning. W. V. Cruess and A. W. Christie. (Calif. Sta. Circ. 276, pp. 37, figs. 11. Mar., 1924.)
A gaseous fermentation of tomato pulp and related products. F. L. Mickle and R. S. Breed. (N. Y. State Sta. Tech. Bul. 110, pp. 27. Jan., 1925.)
Vinegar fermentation and home production of cider vinegar. A. R. Lamb and E. Wilson. (Iowa Sta. Bul. 218, abridged ed., pp. 4. Aug., 1923.)

ANIMAL PRODUCTION

ANIMAL NUTRITION AND FEEDING STUFFS

Studies in nutrition. P. Menaul. (Okla. Sta. Bul. 152, pp. 13, figs. 5.)
The relation of feed consumed to protein and energy retention. A. G. Hogan, L. A. Weaver, A. T. Edinger, and E. A. Trowbridge. (Mo. Sta. Research Bul. 73, pp. 42, figs. 29. Jan., 1925.)
The influence of ultra-violet light on nutrition in poultry. J. M. Murray, C. C. Little, and W. T. Bowie. (Me. Sta. Bul. 320, pp. 139-164, pls. 9, figs. 2. Dec., 1924.)
Calcium metabolism in the laying hen, II. G. D. Buckner, J. H. Martin, and A. M. Peter. (Ky. Sta. Bul. 252, pp. 36, figs. 2. Mar., 1924.)
The effect of varying feed levels on the physiological economy of steers. E. G. Ritzman and F. G. Benedict. (N. H. Sta. Tech. Bul. 26, pp. 34. June, 1924.)
The effect of high and low protein content on the digestibility and metabolism of dairy rations. E. A. Perkins and G. F. Monroe. (Ohio Sta. Bul. 376, pp. 83-116, figs. 4. May, 1924.)
A study of the principal changes which take place in the making of silage. W. H. Peterson, E. G. Hastings, and E. B. Fred. (Wis. Sta. Research Bul. 61, pp. 33, figs. 5. Jan., 1925.)
Production and feeding of silage. L. J. Stadler, M. M. Jones, C. W. Turner, and P. M. Bernard. (Mo. Sta. Bul. 226, pp. 23, figs. 9. Dec., 1924.)
Legume forages with corn and cane for silage. H. E. Dvorachek, F. H. Herzer, R. H. Mason, H. E. Reed, and E. Martin. (Ark. Sta. Bul. 196, pp. 14. Apr., 1925.)
The sunflower as a silage crop.—Feeding value for dairy cows; composition and digestibility when ensiled at different stages of maturity. W. B. Nevens. (Ill. Sta. Bul. 253, pp. 183-225, figs. 2. July, 1924.)
Acidity in relation to quality in sunflower silage. M. J. Blish. (Mont. Sta. Bul. 163, pp. 13. Jan., 1924.)
Nutritive properties of pinto beans and pinto bean straw and their use as feed for cattle. H. W. Titus. (N. Mex. Sta. Bul. 143, pp. 73. May, 1924.)
A bibliography of researches bearing on the composition and nutritive value of corn and corn products. M. H. Keith. (Ill. Sta. Bul. 257, pp. 151. Feb., 1925.)
Soft corn—how to store and feed it. (Ill. Sta. Circ. 293, pp. 16, figs. 7. Oct., 1924.)
Ensiling versus drying soft ear corn. J. M. Evvard, A. R. Lamb, E. J. Maynard, and H. D. Hughes. (Iowa Sta Bul. 216, abridged ed., pp. 4. July, 1923.)
Rations for hogs, dairy cows, beef cattle, horses, and sheep. (Okla. Sta. Circ. 57, pp. 8.)
The production of volatile fatty acids in the intestinal tract of calves fed whole milk or cereal gruel. L. C. Norris. (N. Y. Cornell Sta. Mem. 90, pp. 32, fig. 1. Apr., 1925.)
Milk substitutes in the rearing of young calves J. B. Lindsey and J. G. Archibald. (Mass. Sta. Bul. 223, pp. 41-51. Mar., 1925.)
Vitamins in live-stock feeding. H. H. Mitchell and M. H. Keith. (Ill. Sta. Circ. 282, abs., pp. 4. June, 1924.)
Mineral feeds for farm animals. J. Sotola, R. T. Smith, E. V. Ellington, and L. W. Cassel. (Wash. Col. Sta. Pop. Bul. 127, pp. 19, figs. 7. Apr., 1924.)

HORSES AND MULES

Feeding work horses. M. W. Harper. (N. Y. Cornell Sta. Bul. 437, pp. 59, fig. 1. Feb., 1925.)
Feeding purebred draft fillies. J. L. Edmonds and C. W. Crawford. (Ill. Sta. Bul. 262, pp. 245-260, figs. 13. Apr., 1925.)
Alfalfa and horses. R. S. Hudson. (Mich. Sta. Circ. 65, pp. 7, fig. 1. Nov., 1924.)
Corn versus oats for work mules. E. A. Trowbridge. (Mo. Sta. Circ. 125, pp. 4, figs. 3. July, 1924.)

BEEF CATTLE

Cattle feeding.—Winter steer feeding. J. H. Skinner and F. G. King. (Ind. Sta. Bul. 281, pp. 22, fig. 1. June, 1924.)
Cattle feeding.—Winter steer feeding 1923-24. J. H. Skinner and F. G. King. (Ind. Sta. Bul. 291, pp. 23, fig. 1. Feb., 1925.)
Beef cattle feeding experiments. H. Hackedorn, J. Sotola, and R. P. Bean. (Wash. Col. Sta. Bul. 186, pp. 26, figs. 7. Nov., 1724.)
Preliminary report on range cow supplemental feeding. J. L. Lantow and M. G. Snell. (N. Mex. Sta. Bul. 144, pp. 8. June, 1924.)
Effects of winter rations on pasture gains of beef calves and yearlings. E. W. Sheets and R. H. Tuckwiller. (W. Va. Sta. Bul. 186, pp. 34, figs. 13. Aug., 1924.)
Steer feeding experiments.—Corn silage versus corn and soy bean silage. Velvet bean-and-pod meal, cottonseed meal, and varying proportions of corn and velvet bean-and-pod meal. Corn, sorghum, and sunflower silages. C. J. Goodell. (Miss. Sta. Bul. 222, pp. 16, fig. 1. May, 1924.)
Limited use of shelled corn in fattening two-year-old cattle. E. A. Trowbridge and E. A. Fox. (Mo. Sta. Bul. 218, pp. 15, figs. 6. Aug., 1924.)
The use of a limited amount of molasses in feeding yearling steers. E. A. Trowbridge. (Mo. Sta. Bul. 223, pp. 16, fig. 1. Oct., 1924.)
Cattle feeding in relation to farm management. H. C. M. Case and K. H. Myers. (Ill. Sta. Bul. 261, pp. 213-243, figs. 8. Mar., 1925.)

SHEEP AND GOATS

Scrub vs. purebred ram. A. E. Barlow. (Okla. Sta. Bul. 151, pp. 4, figs. 2.)
Winter feeding of breeding ewes. W. E. Joseph. (Mont. Sta. Bul. 164, pp. 16, figs. 4. Feb., 1924.)
Sheep feeding.—XII, Fattening western lambs, 1923–1924. J. H. Skinner and F. G. King. (Ind. Sta. Bul. 282, pp. 12, fig. 1. July, 1924.)
Fattening western lambs, 1923–1924. H. D. Fox. (Nebr. Sta. Bul. 204, pp. 24, fig. 1. Dec., 1924.)
Lamb feeding experiments at the Irrigation Branch Experiment Station in 1922–23 and 24. H. Hackedorn, R. P. Bean, and J. Sotola. (Wash. Col. Sta. Bul. 185, pp. 42, figs. 5. Nov., 1924.)
Some lamb-feeding results secured by the Kansas Agricultural Experiment Station. A. M. Paterson. (Kans. Sta. Circ. 108, pp. 8, fig. 1. Nov., 1924.)
Lamb feeding investigations, 1922–23. A. M. Paterson and H. W. Marston. (Kans. Sta. Circ. 109, pp. 4, fig. 1. Nov., 1924.)
Forage crops for lambs. J. W. Wilson and A. H. Kuhlman. (S. Dak. Sta. Bul. 207, pp. 659-674. May, 1924.)
Fattening lambs with barley and alfalfa. C. E. Fleming. (Nev. Sta. Bul. 106, pp. 14, figs. 5. Sept., 1924.)
The soybean crop for fattening western lambs. W. G. Kammlade and A. K. Mackey. (Ill. Sta. Bul. 260, pp. 197–211, figs. 2. Mar., 1925.)
A survey of sheep production on 200 farms in northeastern North Dakota and northwestern Minnesota and the general sheep situation. R. D. Jennings et al. (N. Dak. Sta. Bul. 186, pp. 58, figs. 9. Jan., 1925.)
Sheep.—Care and management. A. E. Darlow. (Okla. Sta. Circ. 58, pp. 8, fig. 1.)
Sheep management in southwest Virginia as shown by a survey of 100 farms. C. R. Nobles. (Va. Sta. Bul. 238, pp. 20, fig. 1. Dec., 1924.)
The influence of individuality, age, and season upon the weights of fleeces produced by Angora goats under range conditions. J. L. Lush and J. M. Jones. (Tex. Sta. Bul. 320, pp. 54, figs. 13. Mar., 1924.)

SWINE

Swine feeding investigations, 1922–23. B. M Anderson and H. W. Marston. (Kans. Sta. Circ. 112, pp. 8, figs. 4. Apr., 1925.)
Feeding spring pigs for market. C. M. Vestal. (Ind. Sta. Bul. 279, pp. 15, figs. 5. Feb., 1924.)
Feeding brood sows and growing the litters. W. E. Joseph. (Mont. Sta. Bul. 165, pp. 18 + IX, figs. 6. May, 1924.)
Food requirements and cost of gains of spring and fall pigs. E. F. Ferrin and M. A. McCarty. (Minn. Sta. Bul. 213, pp. 18, figs. 2. June, 1924.)
Feeding pigs in a dry lot. W. E. Joseph. (Mont. Sta. Bul. 169, pp. 52, figs, 19. Dec., 1924.)
Peanuts for fattening hogs in dry lot. J. C. Grimes and W. D. Salmon. (Ala. Sta. Bul. 223, pp. 12. June, 1924.)
Peanut meal as protein supplement to corn for fattening hogs in the dry lot. J. C. Grimes and W. D. Salmon. (Ala. Sta. Bul. 224, pp. 16. Aug., 1924.)
Potatoes as a feed for fattening pigs. J. W. Wilson and A. H. Kuhlman. (S. Dak. Sta. Bul. 209, pp. 691–710, figs. 2. May, 1924.)
Hogging down corn and soy beans. L. A. Weaver. (Mo. Sta. Bul. 224, pp. 20, figs. 10. Nov., 1924.)
A simple mineral mixture for fattening pigs. J. C. Grimes and W. D. Salmon. (Ala. Sta. Bul. 222, pp. 10, figs. 2. Feb., 1924.)
Swine judging. R. T. Smith. (Wash. Sta. Pop. Bul. 130, pp. 27, figs. 21. Sept., 1924.)

POULTRY

Breeding for increased egg production. P. G. Riley. (Ind. Sta. Circ. 119, pp. 15, figs. 11. July, 1924.)
Seasonal and annual egg-production-correlation tables. G. W. Hervey. (N. J. Stas. Bul. 402, pp. 15. Sept., 1924.)
Egg production, monthly costs and receipts on New Jersey poultry farms. W. H. Allen. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 4, pp. 4. Jan., 1925.)
A statistical study of egg production in four breeds of the domestic fowl.—I, Egg production in Wyandottes. L. C. Dunn. (Conn. Storrs Sta. Bul. 117, pp. 17–88, figs. 8. Apr., 1924.)
A statistical study of egg production in four breeds of the domestic fowl.—II, Egg production of Rhode Island Reds. L. C. Dunn. (Conn. Storrs Sta. Bul. 118, pp. 89–140, figs. 6. May, 1924.)
A statistical study of egg production in four breeds of the domestic fowl.—III, Egg production of Plymouth Rocks. L. C. Dunn. (Conn. Storrs Sta. Bul. 122, pp. 215–277, figs. 6. July, 1924.)
Standard methods of feeding laying stock. F. H. Clickner. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 9, pp. 4, fig 1. June, 1925.)
Importance of green feed for poultry. W. H. Allen. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 7, pp. 4, fig. 1. Apr., 1925.)
The value of certain protein feeds for production and quality in eggs. Three years' work—1920–23. R. T. Parkhurst. (Idaho Sta. Bul. 134, pp. 8, figs. 3. May, 1924.)
The influence of animal and vegetable proteins on egg production. H. L. Kempster. (Mo. Sta. Bul. 225, pp. 16, figs. 6. Nov., 1924.)
Comparative influences of various protein feeds on laying hens. R. M. Sherwood. (Tex. Sta. Bul. 317, pp. 24. Feb., 1924.)
A study of the relative values of certain succulent feeds and alfalfa meal as sources of vitamin A for poultry. D. E. Davis and J. R. Beach. (Calif. Sta. Bul. 384, pp. 14. Mar. [Feb.], 1925.)
Feeding baby chicks. H. L. Kempster. (Mo. Sta. Circ. 133, pp. 4. Mar., 1925.)
New chick feeding facts. E. B. Hart, H. Steenbock, J. G. Halpin, and O. N. Johnson. (Wis. Sta. Bul. 371, pp. 24, figs. 16. Nov., 1924.)
Raising chicks at a profit. J. Vandervort. (Ill. Sta. Circ. 294, pp. 15, figs. 6. Apr., 1925.)
Report of egg-laying contest for 1924. R. R. Hannas and F. H. Clickner.. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 3, pp. 4. Dec., 1924.)
Rules and regulations for the Utah intermountain egg-laying contest. B. Alder. (Utah Sta. Circ. 52, pp. 4. July, 1924.)
The present outlook for the poultryman. G. W. Hervey and C. S. Platt. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 5. pp. 4, figs. 3. Feb., 1925.)
The research program of the department of poultry husbandry. W. C. Thompson. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 1, pp. 4, fig. 1. Oct., 1924.)
Observations on European poultry farming. W. C. Thompson. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 11, pp. 4, fig. 1. Aug., 1924.)

DAIRYING

Better sires—better stock.—Build better by breeding. H. P. Davis (Nebr. Sta. Circ. 24, pp. 24, figs. 8. Oct., 1924.)
Purebred dairy sires, their value and influence on production. T. M. Olson and R. M. Gilcreast. (S. Dak. Sta. Bul. 206, pp. 631–658, figs. 23. May, 1924.)
A comparison of Holstein-Friesian sires, based on the average "mature equivalent" fat production of the daughters. C. W. Turner and A. C. Ragsdale. (Mo. Sta. Bul. 217. pp. 32, figs. 2. July, 1924.)
Selection and management of the dairy bull. A. C. Ragsdale. (Mo. Sta. Circ. 127, pp. 10, figs. 9. Aug., 1924.)
Interpretation of dairy pedigrees. J. W. Gowen. (Me. Sta. Bul. 318, pp. 53–80, figs. 5. July, 1924.)
The change of form with age in the dairy cow. S. Brody and A. C. Ragsdale. (Mo. Sta. Research Bul. 67, pp. 48, figs. 40. Sept., 1924.)

The relation between age, weight, and fat production in dairy cows. C. W. Turner, A. C. Ragsdale, and S. Brody. (Mo. Sta. Bul. 221, pp. 12, figs. 5. Sept., 1924.)
The relation of feeding and age of calving to the development of dairy heifers. O. E. Reed, J. B. Fitch, and H. W. Cave. (Kans. Sta. Bul. 233, pp. 38, figs. 8. July, 1924.)
Feeding the dairy herd. C. H. Eckles and O. G. Schaefer. (Minn. Sta. Bul. 218, pp. 48, figs. 3. Dec., 1924.)
Feeding cocoa meal to dairy cows. H. B. Ellenberger and J. A. Newlander. (Vt. Sta. Bul. 243, pp 20, figs. 2. Dec., 1924.)
Ground sorgo seed as a feed for dairy cows. H. W. Cave and J. B. Fitch. (Kans. Sta. Circ. 110. pp. 8. Apr., 1925.)
Corn silage in a dairy ration. W. E. Carroll. (Utah Sta. Bul. 190, pp. 11, fig. 1. Aug., 1924.)
A comparison of early, medium, and late maturing varieties of silage corn for milk production. G. C. White, L. M. Chapman, W. L. Slate, jr., and B. A. Brown. (Conn. Storrs Sta. Bul. 121. pp. 171–211, figs. 5. May, 1924.)
Sunflowers as a silage crop for dairy cows. W. B. Nevens. (Ill. Sta. Bul. 253, abs., pp. 4, figs. 2. July, 1924.)
The minimum protein requirements for growing dairy heifers. W. W. Swett, C. H. Eckles, and A. C. Ragsdale. (Mo. Sta. Research Bul. 66, pp. 155. figs. 11. Mar., 1924.)
Soybean oil meal and ground soy beans as protein supplements in the dairy ration. L. H. Fairchild and J. W. Wilbur. (Ind. Sta. Bul. 289, pp. 20, fig. 1. Dec., 1924.)
Raising dairy calves. E. Weaver, J. M. Shaw, and F. Ely. (Iowa Sta. Circ. 91, pp. 23, figs. 5. May, 1924.)
Raising the dairy calf when whole milk is sold. C. H. Eckles and T. W. Gullickson. (Minn. Sta. Bul. 215, pp. 30, figs. 14. June, 1924.)
Make the dairy pay. Testing and handling milk and cream. F. E. Ball. (Colo. Sta. [Bul.] 295, pp. 60, figs. 34. Dec., 1924.)
Relation of solids in milk to fat and specific gravity of the milk. O. R. Overman, F. A. Davidson, and F. P. Sanmann. (Ill. Sta. Bul. 263, pp. 263–271, fig. 1. Apr., 1925.)
A simple method for determining the keeping quality of milk. J. M. Fuller, H. F. DePew, and B. E. Huggins. (N. H. Sta. Circ. 23, pp. 12. June, 1924.)
Factors affecting the percentage of fat in cows' milk. C. W. Turner. (Mo. Sta. Bul. 222, pp. 22, figs. 11. Oct., 1924.)
Effect of the process of manufacture on the germ content of bulk condensed milk. H. A. Ruehe. (N. Y. Cornell Sta. Mem. 76, pp. 18, figs. 3. July, 1924.)
Filtration and clarification of milk. A. C. Dahlberg and J. C Marquardt. (N. Y. State Sta. Tech. Bul. 104, pp. 27, pls. 4, fig. 1. July, 1924.)
Successful cream whipping. J. C. Hening. (N. Y. State Sta. Circ. 77, pp. 4, figs. 2. Sept., 1924.)
Cooling cream on the farm for buttermaking. V. C. Manhart. (Ind. Sta. Bul. 290, pp. 8, figs. 6. Jan., 1925.)
An accurate method of ice cream mixes. G. D. Turnbow and C. M. Titus. (Hilgardia [Calif. Sta.], vol. 1, No. 4, pp. 57–79. May, 1925.)
Sandiness in ice cream. P. S. Lucas and G. Spitzer. (Ind. Sta. Bul. 286, pp. 12. Jan., 1925.)
Factors affecting the yield of ice cream. H. W. Gregory and V. G. Manhart. (Ind. Sta. Bul. 287, pp. 31. Nov., 1924.)
The effect of the sugar content in the manufacture of commercial ice cream. W. H. E. Reid. (Mo. Sta. Research Bul. 69, pp. 15, figs. 5. Sept., 1924.)
The effect of different percentages of butterfat on the physical properties of ice cream. D. H. Nelson and W. H. E. Reid. (Mo. Sta. Research Bul. 70, pp. 24, figs. 20. Oct., 1924.)
Effect of several ingredients used in the manufacture of commercial ice cream on the change in temperature during the freeezing process. W. H.E. Reid and D. H. Nelson. (Mo. Sta. Research Bul. 71, pp. 16, figs. 8. Nov., 1924.)
Ice cream formulas and standardization. H. P. Davis, P. A. Downs, and B. Masurovsky. (Nebr. Sta. Bul. 203, pp. 23. Nov., 1924.)
The texture of ice cream. A. C. Dahlberg. (N. Y. State Sta. Tech. Bul. 111, pp. 42, pls. 4, fig 1. Mar., 1925.)
Soft cheeses that are easily made. E. F. Goss. (Iowa Sta. Circ. 94, pp. 7, figs. 6. Oct., 1924.)
Elimination of germs from dairy utensils.—III, Steaming cans over a jet. M. J. Prucha and H. H. Harding. (Ill. Sta. Bul. 254, pp. 227–234. Aug., 1924.)
Milking machines.—VIII, The sanitary efficiency of a simplified type of milking machine. F. L. Mickle. (N. Y. State Sta. Bul. 524, pp. 48, pls. 12. Nov.. 1924.)
The bacterial flora of milking machines. A. H. Robertson. (N. Y. State Sta. Tech. Bul. 105, pp. 52. July, 1924.)
Economic studies of dairy farming in New York.—II, Grade A milk with and without cash crops. E. G. Misner. (N. Y. Cornell Sta. Bul. 433, pp. 147, figs. 19. Oct., 1924.)

DISEASES OF LIVESTOCK

The relation of the subcutaneous administration of living *Bacterium abortum* to the immunity and carrier problem of bovine infectious abortion. G. H. Hart and J. Traum. (Calif. Sta. Tech. Paper 19, pp. 50. Apr., 1925.)
Infectious abortion (fifth report). G. C. White, L. F. Rettger, and J. G. McAlpine. (Conn. Storrs Sta. Bul. 123, pp. 281–303, figs. 2. Aug., 1924.)
Infectious abortion in cattle. Sixth report. Methods of conducting the agglutination and complement fixation tests, and their diagnostic value. L. F. Rettger, J. G. McAlpine, and G. C. White. (Conn. Storrs Sta. Bul. 125, pp. 23. Dec., 1924.)
Infectious abortion investigations. H. F. Lienhardt, C. H. Kitselman, and C. E. Sawyer. (Kans. Sta. Tech. Bul. 14, pp. 23, fig. 1. Feb., 1925.)
Studies on a non-virulent living culture of *Bact. abortus* towards protective vaccination of cattle against bovine infectious abortion (Bang's abortion disease). I. F. Huddleson. (Mich. Sta. Tech. Bul. 65, pp. 36. July, 1924.)
The significance of *Bacterium abortus* antibodies (agglutinins and complement-fixing) found in the sera of calves at birth or after nursing. I. F. Huddleson and D. E. Hasley. (Mich. Sta. Tech. Bul. 66, pp. 16. Dec., 1924.)
Observations of the effect of *B. abortus* Bang on the weight of the spleen of the guinea pig. C. P. Fitch and R. E. Lubbehusen. (Minn. Sta. Tech. Bul. 24, pp. 23, figs. 7. Aug., 1924.)
Contagious abortion in cattle. F. B. Hadley. (Wis. Sta. Bul. 368, pp. 24, figs. 6. July, 1924.)
Normal immunity reactions of the cow and the calf with reference to antibody transmission in the colostrum. J. B. Nelson. (Mo. Sta. Research Bul. 68, pp. 30. Aug., 1924.)
A study of the physiologic and pathologic changes occurring in the reproductive organs of the cow following parturition. W. L. Boyd. (Minn. Sta. Tech. Bul. 23, pp. 39, pls. 8. Mar., 1925.)
Field and laboratory notes on a fatal disease of cattle occurring on the coastal plains of Texas (loin disease). H. Schmidt. (Tex. Sta. Bul. 319, pp. 32, figs. 8. Feb., 1924.)
The experimental transmission of swamp fever or infectious anemia by means of secretions. J. W. Scott. (Wyo. Sta. Bul. 138, pp. 62, figs. 12. June, 1924.)
An inquiry into the cause of the increase of tuberculosis in swine. L. Van Es and H. M. Martin. (Nebr. Sta. Research Bul. 30, pp. 78, pls. 16, figs. 3. Feb., 1925.)
Tuberculosis of swine. L. Van Es. (Nebr. Sta. Circ. 25, pp. 27, figs. 10. Feb., 1925.)
Anthelmintic experiments with hogs. D. C. Mote. (Ohio Sta. Bul. 378, pp. 153–182. June, 1924.)
A study of the dietary relationships and the pathology of "stiffness" in swine. L. A Maynard, S. A. Goldberg, and R. C. Miller. (N. Y. Cornell Sta. Mem. 86, pp. 34, pls. 4, figs. 3. Feb., 1925.)

Bacillary white diarrhea of chicks. I. E. Newsom. (Colo. Sta. Bul. 293, pp. 8, figs. 4. Sept., 1924.)
Control of bacillary white diarrhoea, 1923-1924. G. E. Gage and O. S. Flint. (Mass. Sta. Control Ser. Bul. 27, pp. 8. July, 1924.)
Botulism in fowls, types A and C, commonly called limberneck. R. Graham and I. B. Boughton. (Ill. sta. Circ. 289, pp. 4, figs. 5. July, 1924.)
Fowl cholera. R. Graham and I. B. Boughton. (Ill. Sta. Circ. 286, pp. 8, figs. 5. July, 1924.)
Fowl cholera. J. J. Black. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 12, pp. 4. Sept., 1924.)
Coccidiosis of poultry. R. Graham and E. A. Tunnicliff. (Ill. Sta. Circ. 288, pp. 8, figs. 9. July, 1924.)
Fowl plague—its cause, symptoms, and control. F. R. Beaudette. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 8, pp. 4. May, 1925.)
Tuberculosis of fowls. R. Graham and E. A. Tunnicliff. (Ill. Sta. Circ. 285, pp. 7, figs. 5. July, 1924.)
Tuberculosis in poultry. H. Welch. (Mont. Sta. Circ. 127, pp. 11, figs. 7. July, 1924.)
Fowl typhoid. R. Graham and E. A. Tunnicliff. (Ill. Sta. Circ. 287, pp. 4, figs. 3. July, 1924.)
Studies on a nutritional disease of poultry caused by vitamin A deficiency. J. R. Beach. (Calif. Sta. Bul. 378, pp. 22, figs. 7. May, 1924.)
The examination of eggs from infected and immunized hens with germicidal tests on albumen and blood serum. H. G. May. (R. I. Sta. Bul. 197, pp. 47. May, 1924.)
Prevention and control of poultry diseases. L. D. Bushnell and W. R. Hinshaw. (Kans. Sta. Circ. 106, pp. 78, figs. 25. July, 1924.)
The preparation and sending of specimens for laboratory diagnosis. F. R. Beaudette. (N. J. Stas. Hints to Poultrymen, vol. 12, No. 10, pp. 4, fig. 1. July, 1924.)
White snakeroot poisoning. R. Graham and I. B. Boughton. (Ill. Sta. Circ. 295, pp. 7, figs. 4. May, 1925.)

AGRICULTURAL ENGINEERING

Motor driven irrigation pumping plants and the electrical district. G. E. P. Smith. (Ariz. Sta. Bul. 99 pp. 61-141, pl. 1, figs. 20. Mar., 1924.)
A discussion of certain Colorado River problems. G. E. P. Smith. (Ariz. Sta. Bul. 100, pp. 137-175, fig. 1. Feb., 1925.)
Use and waste of irrigation. G. E. P. Smith. (Ariz. Sta. Bul. 101, pp. 265-293, figs. 11. Mar., 1925.)
Measurement of irrigation water. H. E. Murdock and J. R. Barker. (Mont. Sta. Circ. 126, pp. 39, figs. 26. June, 1924.)
Supplemental irrigation for the Willamette Valley, W. L. Powers. (Oreg. Sta. Circ. 57, pp. 8, figs. 2. Aug., 1924.)
Cache County Water Conservation District No. 1. W. Peterson, G. D. Clyde, D. S. Jennings, M. D. Thomas, and K. Harris. (Utah Sta. Bul. 193, pp. 47, figs. 12. Apr., 1925.)
Pumping for drainage in the San Joaquin Valley, California. W. W. Weir. (Calif. Sta. Bul. 382, pp. 38, figs. 18. Jan., 1925.)
Farm drainage methods.—Survey and design, 1908-1922. H. B. Roe. (Minn. Sta. Bul. 216, pp. 71, figs. 23. June, 1924.)
Farm drainage methods.—Construction, 1908-1922. H. B. Roe. (Minn. Sta. Bul. 217, pp. 44, figs. 52. June, 1924.)
Drain wet fields. E. R. Jones and O. R. Zeasme (Wis. Sta. Bul. 365, pp. 24, figs. 20. June, 1924.)
Investigations in stump and stone removal. M. J. Thompson and A. J. Schwantes. (Minn. Sta. Bul. 208, pp. 43, figs. 11. Mar., 1924.)
Dairy barns and equipment. W. A. Foster and E. Weaver. (Iowa Sta. Circ. 93, pp. 31, figs. 22. Oct., 1924.)
Building the dairy barn. N. S. Fish. (Wis. Sta. Bul. 369, pp. 31, figs. 27. Aug., 1924.)
Why build a silo?—And how? J. C. Wooley, E. A. Trowbridge, and A. C. Ragsdale. (Mo. Sta. Bul. 214, pp. 16, figs. 13. June, 1924.)
The self-feeder as a labor saver. H. E. Dvorachek and H. A. Sandhouse. (Ark. Sta. Bul. 191, pp. 10, figs. 3. May, 1924.)
Home made labor saving devices for the hog farm. J. C. Wooley. (Mo. Sta. Circ. 131, pp. 12, figs. 21. Dec., 1924.)
A colony brooder house that starts chicks right. L. E. Card and F. P. Hanson. (Ill. Sta. Circ. 291, pp. 12, figs. 17. Aug., 1924.)
The 30 × 30 Missouri poultry house. H. L. Kempster. (Mo. Sta. Circ. 129, pp. 8, figs. 6. Oct., 1924.)
Materials for poultry-house construction. E. R. Gross. (N. J. Stas. Hints to Poultrymen, vol. 13, No. 2, pp. 4, figs. 4. Nov., 1924.)
Washington poultry houses. J. S. Carver, G. R. Shoup, W. D. Buchanan, and L. J. Smith. (Wash. Col. Sta. Bul. 188, pp. 88, figs. 46. Jan., 1925.)
Construction and management of the back storage cellar. L. M. Marble and R. D. Anthony. (Pa. Sta. Bul. 191, pp. 32, figs. 16. Jan., 1925.)
Nebraska tractor tests, 1921, 1922, and 1923. E. E. Brackett et al. (Nebr. Sta. Bul. 200, pp. 16, fig. 1. Aug., 1924.)
Farm motor trucks in New York. V. B. Hart. (N. Y. Cornell Sta. Bul. 427, pp. 52+[4], figs. 5. May, 1924.)
The care of farm gas engines. C. C. Johnson. (Wash. Col. Sta. Pop. Bul. 129, pp. 51, figs. 31. July, 1924.)
Hitching horses to get the most work done. E. W. Lehmann and E. T. Robbins. (Ill. Sta. Circ. 283, pp. 8, figs. 7. July, 1924.)
Simple water systems. O. E. Robey. (Mich. Sta. Circ. 64, pp. 16, figs. 19. June, 1924.)
A bacteriological study of a sewage disposal plant. W. H. Gaub, jr. (N. J. Stas. Bul. 394, pp. 24, figs. 4. Mar., 1924.)
Studies on the biology of sewage disposal. Third annual report of the sewage substation for the year ending June 30, 1924. (N. J. Stas. Bul. 403, pp. 95, figs. 39. July, 1924.)
Rural highways. C. P. Halligan. (Mich. Sta. Spec. Bul. 138, pp. 20, figs. 14. Jan., 1925.)

ECONOMICS AND SOCIOLOGY

Increasing farm earnings by the use of simple farm accounts. H. C. M. Case and M. L. Mosher. (Ill. Sta. Bul. 252, pp. 147-182, figs. 8. June, 1924.)
Double entry accounts for farmers. J. A. Hopkins. (Iowa Sta. Circ. 96, pp. 24, figs. 8. Oct., 1924.)
Farm profits. C. T. Dowell. (Okla. Sta. Circ. 56, pp. 13.)
The cost of producing apples in Minnesota, 1916-1920. W. G. Brierley, W. J. Koppen, and G. A. Pond. (Minn. Sta. Bul. 209, pp. 44, figs. 15. Apr., 1924.)
The cost of marketing the apple crop of 1923. L. P. Jefferson. (Mass. Sta. Bul. 224, pp. 9. Mar., 1925.)
The results of a survey to determine the cost of producing beef in California. R. L. Adams. (Calif. Sta. Circ. 281, pp. 22. Dec., 1924.)
Cost of producing milk and dairy farm organization in Spokane and Stevens Counties. G. Severance and G. O. Baker. (Wash. Col. Sta. Bul. 182, pp. 36, figs. 4. Aug., 1924.)
The cost and income of the farm poultry flock. O. R. Johnson and B. H. Frame. (Mo. Sta. Bul. 219, pp. 20, figs. 6. Aug., 1924.)
Cooperating under the Iowa cooperative laws. F. Robotka. (Iowa Sta. Circ. 95, pp. 16. Nov., 1924.)
A study of farm organization and management in Mason and Fleming Counties. W. D. Nicholls, C. U. Jett, and Z. L. Galloway. (Ky. Sta. Bul. 253, pp. 84, figs. 6. June, 1925.)
Organization and management of typical West Virginia farms. A. J. Dadisman. (W. Va. Sta. Bul. 187, pp. 75, figs. 26. Aug., 1924.)
Organization and management of typical West Virginia farms. A. J. Dadisman. (W. Va. Sta. Circ. 38, pp. 4. May, 1925.)
Farm oganization and cost of production on cotton farms in Anderson County, S. C. W. C. Jensen. (S. C. Sta. Bul. 221, pp. 101, figs. 18. Sept., 1924.)
An economic study of dairying on 163 farms in Herkimer County, New York. E. G. Misner. (N. Y. Cornell Sta. Bul. 432, pp. 59, figs. 6. Sept., 1924.)

Economic studies of dairy farming in New York.—II, Grade A milk with and without cash crops. E. G. Misner. (N. Y. Cornell Sta. Bul. 433, pp. 147, figs. 19. Oct., 1924.)
Economic studies of dairy farming in New York.—III, Grade B milk with alfalfa roughage. E. G. Misner. (N. Y. Cornell Sta. Bul. 438, pp. 104, figs. 3. Mar., 1925.)
An economic study of farming in southwestern North Dakota. R. E. Willard and L. A. Reynoldson. (N. Dak. Sta. Bul. 180, pp. 47, figs. 5. July, 1924.)
Economic aspects of creamery organization. J. D. Black and E. S. Guthrie. (Minn. Sta. Tech. Bul. 26, pp. 111, figs. 25. Dec., 1924.)
Dry farming in the Sulphur Spring Valley. G. E. Thompson and F. E. Gray. (Ariz. Sta Bul. 103, pp. 339–357, figs. 9. Apr., 1925.)
Adjusting agricultural production and distribution in south central West Virginia to meet home market demands. W. W. Armentrout, H. T. Crosby, and H. I. Richards. (W. Va. Sta. Bul. 188, pp. 64, figs. 22. Oct., 1924.)
Cooperative central marketing organization. J. D. Black and H. B. Price (Minn. Sta. Bul. 211, pp. 112, figs. 3. Apr., 1924.)
U. S. grades for barreled apples. (N. C. Sta. Farmers' Market Bul., vol. 11, No. 71, pp. 11. Sept., 1924.)
Marketing Michigan potatoes. J. T. Horner. (Mich. Sta. Spec. Bul. 137, pp. 32, figs. 13. Feb., 1925.)
Cooperative livestock marketing in Ohio. B. A. Wallace. (Ohio Sta. Bul. 375, pp. 31–82, fig. 1. Apr., 1924.)
Cooperative dairy marketing plans. T. Macklin. (Wis. Sta. Bul. 367, pp. 24, figs. 6. June, 1924.)
Marketing dairy products. Creameries and cooperative cream shipping stations in North Dakota. A. H. Benton. (N. Dak. Sta. Bul. 182, pp. 40, figs. 21. Oct., 1924.)
The price of feed utilities. G. S. Fraps. (Tex. Sta. Bul. 323, pp. 24, figs. 5. Sept., 1924.)
Successful threshing ring management. E. Rauchenstein and C. A. Bonnen. (Ill. Sta. Bul. 267, pp. 373–403, figs. 2. May, 1925.)
Advertising farm products by farmers and farm organizations. A. H. Benton. (N. Dak. Sta. Bul. 185, pp. 32, figs. 25. Jan., 1925.)
The relation between rents and agricultural land values in theory and in practice. F. A. Buechel (Tex. Sta. Bul. 318, pp. 71, figs. 12. Feb., 1924.)
Landlords of Nebraska farms. J. O. Rankin. (Nebr. Sta. Bul. 202, pp. 38, figs. 4. Nov., 1924.)
Tenure and farm investment in Nebraska. J. O. Rankin. (Nebr. Sta. Bul. 205, pp. 36, figs. 5. Feb., 1925.)
Tax revision in Kansas. E. Englund. (Kans. Sta. Bul. 234, pp. 95, figs. 3. Dec., 1924.)
Assessment and equalization of farm and city real estate in Kansas. E. Englund. (Kans. Sta. Bul. 232. pp. 70, figs. 5. July, 1924.)
The organization and development of cooperative fire insurance companies in New York. R. W. Bartlett. (N. Y. Cornell Sta. Bul. 435, pp. 36, figs. 7. Dec., 1924.)
The Metropolis Reclamation Project.—A survey of farm, home, and social conditions upon a project still in an early state of development. J. C. Lambert. (Nev. Sta. Bul. 107, pp. 30, figs. 6. Nov., 1924.)
Rural social survey of Hudson, Orange, and Jesup consolidated school districts, Blackhawk and Buchanan Counties, Iowa. G. H. Von Tungeln and H. L. Eells. (Iowa Sta. Bul. 224, pp. 201–251, figs. 21. Nov., 1924.)
The organization and direction of clothing clubs. H. M. Phillips, F. Mallory, and M. Haugh. (Ill. Sta. Circ. 280, pp. 43, figs. 6. Apr., 1924.)
An economic study of rural store credit in New York. L. Spencer. (N. Y. Cornell Sta. Bul. 430, pp. 47. Sept., 1924.)
The cost of living in a small factory town. C. V. Noble. (N. Y. Cornell Sta. Bul. 431, pp. 70, fig. 1. Sept., 1924.)
Rural religious organization.—A study of the origin and development of religious groups. J. H. Kolb and C. J. Bornman. (Wis. Sta. Research Bul. 60, pp. 63, figs. 18. June, 1924.)
Tourist camps. C. P. Halligan. (Mich. Sta. Spec. Bul. 139, pp. 18, figs. 16. Jan., 1925.)
Outlines of courses of instruction in agricultural nature study for the rural schools of California. O. J. Kern. (Calif. Sta. [Pub.], pp. 100, figs. 60. Revised Dec., 1924.)

REPORTS, PERIODICALS, REGULATORY AND MISCELLANEOUS PUBLICATIONS

REPORTS

Report of the Alaska Agricultural Experiment Stations, 1923. C. C. Georgeson. pp. 37, figs. 24.
Report of the college of agriculture and the agricultural experiment station of the University of Calfornia, July 1, 1922, to June 30, 1923. T. F. Hunt, C. M. Haring, et al. pp. 476, pls. 2, figs. 177.
Report of the agricultural experiment station of the University of California from July 1, 1923, to June 30, 1924. E. D. Merrill. pp. 84.
The thirty-seventh annual report of the Colorado Agricultural Experiment Station for the year 1924. C. P. Gillette et al. pp. 42.
Forty-seventh annual report of the Connecticut Agricultural Experiment Station, being the annual report for the year ended October 31, 1923. W. L. Slate, jr., et al. pp. VIII+534+XLVIII, pls. 26, figs. 84.
Report of the director for the year ending October 31, 1924. W. L. Slate, jr., et al. (Conn. State Sta. Bul. 264, pp. 195–219, figs. 6. Jan. 1925.)
Biennial reports of the Storrs Agricultural Experiment Station, Storrs, Connecticut, 1920–1923. E. H. Jenkins. pp. XIII.
Thirty-sixth annual report of the Storrs Agricultural Experiment Station, Storrs, Connecticut, for the year ending June 30, 1924. W. L. Slate, jr., et al. pp. 396, figs. 99.
Annual report of the director [Delaware Agricultural Experiment Station] for the fiscal year ending June 30, 1924. C. A. McCue. pp. 30.
University of Florida Agricultural Experiment Station report for fiscal year ending June 30, 1923. W. Newell et al. pp. 140R+VII, figs. 21.
Thirty-seventh annual report Georgia Experiment Station for the year 1924. H. P. Stuckey. pp. 59–89, figs. 11.
Report of the Guam Agricultural Experiment Station, 1922. C. W. Edwards et al. pp. 20, pls. 6.
Report of the Guam Agricultural Experiment Station, 1923. C. W. Edwards et al. pp. 12, figs. 8.
Report of the Hawaii Agricultural Experiment Station, 1922. J. M. Westgate et al. pp. 23, pls. 9.
Report of the Hawaii Agricultural Experiment Station, 1923. J. M. Westgate et al. pp. 16, pls. 2.
Work and progress of the agricultural experiment station for the year ended December 31, 1923. E. J. Iddings. (Idaho Sta. Bul. 133, pp. 19. Jan., 1924.)
Work and progress of the agricultural experiment station for the year ended December 31, 1924. E. J. Iddings. (Idaho Sta. Bul. 135, pp. 55, fig. 1. Jan., 1925.)
Thirty-sixth annual report agricultural experiment station [of the] University of Illinois, 1921 1923. H. W. Mumford. pp. 24.
Thirty-seventh annual report of the Purdue University Agricultural Experiment Station, La Fayette Ind., for the year ending June 30, 1924. G. I. Christie and H. J. Reed. pp. 64, figs. 34.
Annual report for fiscal year ending June 30, 1924, agricultural experiment station, Iowa State College of Agriculture and Mechanic Arts. C. F. Curtiss. pp. 64.
Director's report 1922–1924 [Kansas Agricultural Experiment Station], for the biennium July 1, 1922, to June 30, 1924. F D. Farrell. pp. 145, fig. 1. Sept., 1924.

Thirty-fifth annual report of the agricultural experiment station of the University of Kentucky, Lexington, Ky., 1922.—II, Bulletins 239 to 245. Circulars 28 to 30. pp. IV+378+93, figs. 99.
Thirty-sixth annual report of the Kentucky Agricultural Experiment Station for the year 1923. Part I, Report of the director. Meteorological observations. T. Cooper. pp. 59, figs. 2.
The thirty-seventh annual report of the University of Maryland Agricultural Experiment Station, 1923–1924. pp. XIX+300, figs. 78.
Thirty-sixth annual report of the Massachusetts Agricultural Experiment Station. Report of the director for the fiscal year ending Nov. 30, 1923. pp. 15a.
Thirty-sixth annual report of the agricultural experiment station of the Michigan Agricultural College for the year ending June 30, 1923. R. S. Shaw et al. pp. 504, figs. 108.
Thirty-first annual report of the [Minnesota] Agricultural Experiment Station, 1923. W. C. Coffey. pp. 31
[Minnesota] Agricultural Experiment Station, thirty-second annual report.—Part I, Publications, list of projects, financial statement, and staff members, July 1, 1923, to June 30, 1924. W. C. Coffey. pp. 38.
Minnesota Agricultural Experiment Station, thirty-second annual report.—Part II, Popular discussions of some of the experimental work in animal husbandry, dairy husbandry, veterinary medicine, poultry husbandry, and bee culture, 1924. pp. 40, figs. 10.
Thirty-sixth annual report [Mississippi Agricultural Experiment Station] for the fiscal year ending June 30, 1923. J. R. Ricks et al. pp. 63. June, 1923.
New knowledge.—One year's work, agricultural experiment station (report of the director, July 1, 1923, to June 30, 1924). F. B. Mumford. (Mo. Sta. Bul. 228, pp. 86, figs. 14. Jan., 1925.)
Agricultural service from the Montana Experiment Station. Thirtieth annual report, July 1, 1922, to June 30, 1923. F. B. Linfield et al. pp. 71, figs. 32.
Thirty-seventh annual report of the agricultural experiment station of Nebraska, [1923]. E. A. Burnett and W. W. Burr. pp. 43.
Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1923. S. B. Doten et al. pp. 16.
Annual report of the board of control [Nevada Agricultural Experiment Station] for the fiscal year ending June 30, 1924. S. B. Doten et al. pp. 21, figs. 2.
Progress of agricultural experiments—1924. A report of the directer of the New Hampshire Agricultural Experiment Station for the year 1924, including a financial statement for the fiscal year ending June 30, 1924. (N. H. Sta. Bul. 216, pp. 35. Feb., 1925.)
Forty-fourth annual report of the New Jersey State Agricultural Experiment Station and the thirty-sixth annual report of the New Jersey Agricultural College Experiment Station for the year ending June 30, 1923. J. G. Lipman et al. pp. 414, pls. 17, figs. 10.
Thirty-fifth annual report agricultural experiment station of the New Mexico College of Agriculture and Mechanic Arts, 1923–1924. F. Garcia. pp. 55, figs. 2.
Thirty-seventh annual report of the dean [New York State College of Agriculture and Agricultural Experiment Stations], 1924. A. R. Mann. pp. 89.
Forty-third annual report [of the New York State Station] for the fiscal year ended June 30, 1924. R. W. Thatcher. pp. 56.
Forty-sixth annual report of the North Carolina Agricultural Experiment Station for the fiscal year ended June 30, 1923. Statistical report year ending December 1, 1923. B. W. Kilgore, F. E. Miller, F. H. Jeter, et al. pp. 103, pl. 1, figs. 17.
Experiment station progress. Report of director [North Dakota Agricultural Experiment Station], July, 1921, to June 30, 1923. P. F. Trowbridge et al. pp. 100, figs. 25.
Forty-third annual report for 1923–24. C. G. Williams. (Ohio Sta. Bul. 382, pp. 68, figs. 16 June, 1924.)
New information for Oklahoma farmers. A biennial report of the Oklahoma Agricultural Experiment Station for 1922–1924. C. T. Dowell. pp. 36, figs. 3.
Thirty-seventh annual report of the director for the fiscal year ending June 30, 1924. (Pa. Sta. Bul. 188, pp. 31, figs. 2. Aug., 1924.)
Report of the Porto Rico Agricultural Experiment Station, 1923. D. W. May et al. pp. 18, pls. 4.
Thirty-sixth annual report of the director of the [Rhode Island] Agricultural Experiment Station [1923]. B. L. Hartwell. pp. 12.
Thirty-seventh annual report of the South Carolina Experiment Station of Clemson Agricultural College for the year ended June 30, 1924. H. W. Barre. pp. 95, figs. 30.
Thirty-sixth annual report of the agricultural experiment station of the University of Tennessee for 1923. C. A. Mooers et al. pp. 31, fig. 1.
Thirty-fifth annual report of the Texas Agricultural Experiment station, 1922. B. Youngblood. pp. 15.
Biennial report of the director for the years 1923 and 1924. W. Peterson. (Utah Sta. Bul. 192, pp. 64, fig. 1. Jan., 1925.)
Report of the Virgin Islands Agricultural Experiment Station, 1923. J. B. Thompson et al. pp. 13, pls, 3, fig. 1.
Thirty-fourth annual report for the fiscal year ended June 30, 1924. E. C. Johnson. (Wash. Col. Sta. Bul. 187, pp. 111. Dec., 1924.)
New pages in farm progress. Annual report of the director, 1923–1924. H. L. Russell, F. B. Morrison, and W. H. Ebling. (Wis. Sta. Bul. 373, pp. 99, figs. 40. Apr., 1925.)
Third annual report, 1922. S. H. Starr. (Ga. Coastal Plain Sta. Bul. 3, pp. 23, figs. 3. June, 1923.)
Fourth annuul report, 1923. S. H. Starr. (Ga. Coastal Plain Sta. Bul. 4, pp. 44, figs. 17. June, 1924.)
Report of Moses Fell Annex, Bedford, Ind., June, 1925. H. J. Reed and E. W. Moore. (Ind. Sta. Circ. 123, pp. 24, figs. 19. June, 1925.)
Report of West Central Experiment Station, Morris, Minn., 1923. P. E. Miller. pp. 49.
Report of Northwest Experiment Station, Crookston, Minn., 1923. C. G. Selvig et al. pp. 113, figs. 8.
Report Raymond Branch Experiment Station, 1923 and 1924. C. B. Anders. (Miss. Sta. Bul. 224, pp. 16. Dec., 1924.)
Report from Holly Springs Branch Experiment Station for 1924. C. T. Ames. (Miss. Sta. Bul 223, pp. 25, fig. 1. Dec., 1924.)
Report South Mississippi Branch Experiment Station, 1922, 1923, and 1924. E. B. Ferris. (Miss. Sta. Bul. 225, pp. 19, figs. 2. Dec., 1924.)
Annual report of the northeast Missouri crops experiment field (1924). W. C. Etheridge and C. A. Helm. (Mo. Sta. Circ. 128, pp. 2. Sept., 1924.)
Dickinson substation report for 1922 and 1923. L. Moomaw. (N. Dak. Sta. Bul. 189, pp. 46, figs. 8. Feb., 1925.)
Twenty-third report of the State Entomologist of Connecticut, 1923. W. E. Britton et al. (Conn. State Sta. Bul. 256, pp. 221–316, pls. 16, figs. 8. Feb., 1924.)
Twenty-fourth report of the State Entomologist of Connecticut, 1924. W. E. Britton et al. (Conn. State Sta. Bul. 265, pp. 221-344, pls. 20, figs. 9. Mar., 1925)
Montana insect pests for 1923 and 1924, being the twentieth report of the State Entomologist of Montana. R. A. Cooley. (Mont. Sta. Bul. 170, pp. 30, figs. 6. Jan., 1925.)
Second report of the Tree Protection Examining Board. W. E. Britton, C. P. Clinton, and W O. Filley. (Conn. State Sta. Bul. 263, pp. 137–192, pls. 8. Dec., 1924.)
The agricultural regions of North Dakota. R. E. Willard. (N. Dak. Sta. Bul. 183, pp. 168, figs. 64. Dec., 1924.)
The Lower Rio Grande Valley of Texas. A. T. Potts. (Tex. Sta. Circ. 34, pp. 15. July, 1924.)

Texas Agricultural Experiment Station system. B. Youngblood. (Tex. Sta. Circ. 33, pp. 40. May, 1924.)
This public domain of ours. G. Stewart. (Utah Sta. Circ. 49, pp. 56, figs. 17. Mar., 1924.)
Agricultural experiment station work (tentative plans). H. G. Knight. (W. Va. Sta. Bul. 193, pp. 32. Dec., 1924.)
Recent results of work of the North Carolina Agricultural Experiment Station and the present program of work. B. W. Kilgore. (N. C. Sta. Bul. 247, pp. 72, figs. 16. Apr., 1925.)
Fact finding for northwestern North Dakota farming—1908–1924. A. C. Kuenning. (N. Dak. Sta. Bul. 180, pp. 36, figs. 6. Feb., 1925.)
Reymann Memorial Farms. H. G. Knight. (W. Va. Sta. Bul. 194, pp. 20, figs. 19. Feb., 1925.)
Some results from agricultural stations over the State. W. L. Quayle. (Wyo. Sta. State Farms Bul. 4, pp. 14, figs. 3. Aug., 1923.)
The service of the State experiment farms. W. L. Quayle. (Wyo. Sta. State Farms Bul. 5, pp. 68, figs. 33. Jan., 1925.)

PERIODICALS

Quarterly Bulletin, Michigan Agricultural Experiment Station.—Vol. 7 (1924), No. 1, pp. 38, figs. 12; No. 2, pp. 41–71, figs. 6; (1925), No. 3, pp. 73–118, figs. 12; No. 4, pp. 121–168, figs. 12.
Farmers' Market Bulletin, North Carolina Agricultural Experiment Station.—Vol. 11 (1924), No. 69, pp. 11; No. 70, pp. 16, figs. 3; No. 72, pp. 8.
Monthly Bulletin, Ohio Agricultural Experiment Station.—Vol. 9 (1924), No. 3–4, pp. 33–72, figs. 5; No. 5–6, pp. 75–104, pl. 1, figs. 11; No. 7–8, pp. 105–136, fig. 1; No. 9–10, pp. 137–184, figs. 21; No. 11–12, pp. 185–223, figs. 14; Vol. 10 (1925), No. 1–2, pp. 32, figs. 6; No. 3–4, pp. 33–64, figs. 5.
Bimonthly Bulletin, Western Washington Experiment Station, Puyallup, Wash.—Vol. 12 (1924), No. 2, pp. 25–51, figs. 9; No. 3, pp. 53–76, figs. 8; No. 4, pp. 77–96, figs. 3; (1925), No. 5, pp. 97–124, figs. 7.

REGULATORY PUBLICATIONS, FERTILIZERS

Fertilizer report for 1924. E. M. Bailey. (Conn. State Sta. Bul. 261, pp. 100. Nov. 1924.)
Commercial fertilizers. E. G. Proulx et al. (Ind. Sta. Bul. 280, pp. 59, fig. 1. May, 1924.)
Analyses of commercial fertilizers. H. E. Curtis, H. R. Allen, and L. Gault. (Ky. Sta. Bul. 251, pp. 369–485. Dec., 1923.)
Commercial fertilizers, 1924. J. M. Bartlett. (Me. Sta. Off. Insp. 113, pp. 37–68. Oct., 1924.)
Inspection of commercial fertilizers. H. D. Haskins, L. S. Walker, and G. B. Dalrymple. (Mass. Sta. Control Ser. Bul. 29, pp. 32. Nov., 1924.)
Testing fertilizers for Missouri farmers, 1924. L. D. Haigh. (Mo. Sta. Bul. 230, pp. 57, fig. 1. Feb., 1925.)
Inspection of commercial fertilizers for 1924. H. R. Kraybill, T. O. Smith, and S. R. Shimer. (N. H. Sta. Bul. 214, pp. 19. Nov., 1924.)
Analyses of commercial fertilizers, fertilizer supplies, and home mixtures for 1924. C. S. Cathcart. (N. J. Stas. Bul. 405, pp. 37, fig. 1. Nov., 1924.)
Analyses of commercial fertilizers and ground bone; analyses of agricultural lime, 1924. C. S. Cathcart. (N. J. Stas. Bul. 409, pp. 35. Dec., 1924.)
Fertilizer registrations for 1925. C. S. Cathcart. (N. J. Stas. Bul. 413, pp. 24. Jan., 1925.)
Commercial fertilizers, 1925 edition. R. H. Robinson. (Oreg. Sta. Circ. 58, pp. 20. Jan., 1925.)
Inspection of fertilizers. J. B. Smith and W. L. Adams. (R. I. Sta. Ann. Fert. Circ., pp. 12. Oct., 1924.)
Analyses of commercial fertilizers. R. M. Bracket and H. M. Stackhouse. (S. C. Sta. Bul. 220, pp. 61. Aug., 1924.)
Commercial fertilizers in 1923–1924. G. S. Fraps and S. E. Asbury. (Tex. Sta. Bul. 322, pp. 61. Sept., 1924.)
Commercial fertilizers. J. L. Hills, C. H. Jones, and G. F. Anderson. (Vt. Sta. Bul. 240, pp. 24. Aug. 1924.)

REGULATORY PUBLICATIONS, FEEDING STUFFS

Report on inspection of commercial feeding stuffs, 1923. E. M. Bailey. (Conn. State Sta. Bul. 257, pp. 317–359. Apr., 1924.)
Commercial feeding stuffs in Kentucky in 1924. J. D. Turner, H. D. Spears, and W. G. Terrell. (Ky. Sta. Bul. 257, pp. 3. Feb., 1925.)
Commercial feeding stuffs, 1923, 1924. J. M. Bartlett. (Me. Sta. Off. Insp. 112, pp. 17–36. Aug., 1924.)
Inspection of commercial feedstuffs. P. H. Smith and F. J. Kokoski. (Mass. Sta. Control Ser. Bul. 28, pp. 35. Nov., 1924.)
Inspection of commercial feeding stuffs, 1924. H. R. Kraybill, T. O. Smith, and J. T. Sullivan. (N. H. Sta. Bul. 213, pp. 63. Aug., 1924.)
Analyses of commercial feeding stuffs and registrations for 1924. C. S. Cathcart et al. (N. J. Stas. Bul. 399, pp. 76, fig. 1. July, 1924.)
Inspection of feeds. J. B. Smith and W. L. Adams. (R. I. Sta. Ann. Feed Circ., pp. 12. Apr., 1925.)
Commercial feeding stuffs. J. L. Hills, C. H. Jones, and G. E. Anderson. (Vt. Sta. Bul. 237, pp. 20. Mar., 1924.)
Commercial feeding stuffs. J. L. Hills, C. H. Jones, and G. E. Anderson. (Vt. Sta. Bul. 242, pp. 32. Oct., 1924.)

REGULATORY PUBLICATIONS, FOODS AND DRUGS

The twenty-eighth report on food products and the sixteenth report on drug products, 1923. E. M. Bailey. (Conn. State Sta. Bul. 255, pp. 161–219. Feb., 1924.)
Foods and drugs. J. M. Bartlett. (Me. Sta. Off. Insp. 111, pp. 16. Apr., 1924.)

REGULATORY PUBLICATIONS, SEEDS

Inspection of agricultual seeds. E. G. Proulx et al. (Ind. Sta. Bul. 285, pp. 63, fig. 1. Jan., 1925.)
Seed analyses, 1921–1924. C. M. King. (Iowa Sta. Bul. 226, pp. 291–311. Feb., 1925.)
Ten years' grain and seed testing in Montana. Annual report of the Montana Grain Inspection Laboratory July 1, 1922, to June 30, 1923. C. McKee and W. O. Whitcomb. (Mont. Sta. Bul. 167, pp. 18, figs. 5. Oct., 1924.)
Results of seed tests for 1924 made for the State Department of Agriculture. M. G. Eastman. (N. H. Sta. Bul. 215, pp. 18. Dec., 1924.)
Results of seed and legume inoculant inspection for 1924. J. G. Fiske. (N. J. Stas. Bul. 412, pp. 72, fig. 1. Mar., 1925.)
Rules for seed testing. M. T. Munn. (N. Y. State Sta. Circ. 73, pp. 16. Feb., 1924.)
Agricultural seed inspection. A. S. Lutman. (Vt. Sta. Bul. 241, pp. 7. Oct., 1924.)

REGULATORY PUBLICATIONS, MISCELLANEOUS

Report on commercial insecticides and fungicides.—I, Text of the insecticide law of Connecticut and regulations for its enforcement. W. L. Slate, jr., and T. Holt. II, Examination of insecticides and fungicides, etc. E. M. Bailey. (Conn. State Sta. Bul. 258, pp. 361–377. June, 1924.)

Analyses of materials sold as insecticides and fungicides during 1924. C. S. Cathcart and R. L. Willis. (N. J. Stas. Bul. 407, pp. 16. Nov., 1924.)

Stallion enrollment.—XIII, Report of stallion enrollment work for the year 1924 with lists of stallions and jacks enrolled. (Ind. Sta. Circ. 120, pp. 48, fig. 1. Dec., 1924.)

Tenth annual report of the dairy department creamery license division for the year ending March 31, 1924. W. G. Goss. (Ind. Sta. Circ. 118, pp. 16, figs. 2.)

Inspection of lime products used in agriculture. H. D. Haskins, L. S. Walker, and G. B. Dalrymple. (Mass. Sta. Control Ser. Bul 30, pp 6, fig. 1. Dec., 1924.)

PUBLICATION LISTS AND MISCELLANEOUS

Publications available for free distribution. (Idaho Sta. Circ. 37, pp. 4. Jan., 1925.)

Information regarding recent publications. (Kans. Sta. Circ. 111, pp. 4. Apr., 1925.)

Abstracts of papers not included in bulletins, finances, meteorology, index. (Me. Sta. Bul. 315, pp. 95–118 + XI. Dec., 1923.)

Bulletin summary. (Mass. Sta. Circ. 71, pp. 4. Feb., 1924.)

Summary of publications. B. C. Pittman. (Utah Sta. Circ. 53, pp. 4. Sept., 1924.)

INCOME, EXPENDITURES, AND OTHER STATISTICS

By J. I. Schulte

In the following tables will be found detailed data regarding personnel, publications, and mailing lists of the experiment stations; revenues and additions to equipment, 1925; a classified statement of expenditures from the Hatch and Adams funds; and a statement of disbursements from the United States Treasury under the Hatch and Adams Acts from their enactment to the end of the fiscal year, June 30, 1925.

Table 2.—*Personnel, publications, and mailing lists, 1925*

Station	Number on staff	Number of teachers on staff	Number on staff who assist in extension work	Publications during fical year 1924–25		Number of names on mailing list
				Number	Pages	
Alabama (College)	32	14	3	12	60	950
Alabama (Tuskegee)	5	4	----------	----------	----------	----------
Alaska	8	----------	----------	1	37	3,000
Arizona	24	20	1	14	357	6,850
Arkansas	29	23	----------	7	172	4,000
California	150	87	84	60	1,861	13,896
Colorado	45	18	8	12	253	1,700
Connecticut (State)	32	----------	1	14	592	9,373
Connecticut (Storrs)	17	8	----------	12	440	9,000
Delaware	14	8	3	3	93	7,000
Florida	21	1	3	9	266	20,000
Georgia	9	1	1	25	83	9,784
Guam	4	----------	----------	2	32	----------
Hawaii	6	----------	3	6	132	1,500
Idaho	35	19	9	8	198	17,610
Illinois	102	74	30	39	1,372	23,000
Indiana	77	19	----------	33	890	36,760
Iowa	87	26	----------	30	943	37,932
Kansas	82	44	----------	15	572	12,500
Kentucky	58	27	7	7	276	13,500
Louisiana (Sugar) Louisiana (State) Louisiana (North)	22	3	10	2	105	6,500
Maine	14	----------	----------	11	284	20,100
Maryland	39	26	1	7	204	33,000
Massachusetts	50	16	----------	23	230	10,000
Michigan	79	37	10	30	1,284	45,000
Minnesota	125	165	----------	44	1,184	15,600
Mississippi	34	3	----------	9	104	18,000
Missouri (College)	68	56	----------	97	1,460	5,747
Missouri (Fruit)	4	----------	----------	----------	----------	----------
Montana	35	13	4	19	543	6,000
Nebraska	40	20	----------	17	734	12,041
Nevada	9	1	----------	4	77	7,000
New Hampshire	28	20	11	7	147	6,700
New Jersey (State) New Jersey (College)	67 14	41	5	96	1,830	16,300
New Mexico	18	16	2	83	257	9,000
New York (State)	50	----------	----------	27	814	22,800
New York (Cornell)	88	68	27	29	1,788	3,050
North Carolina (College)	45	10	9	6	355	13,876
North Dakota	51	10	----------	12	600	12,000
Ohio	74	11	12	70	826	70,470
Oklahoma	27	29	----------	9	159	17,000
Oregon	56	31	----------	13	312	1,640
Pennsylvania	88	75	----------	8	216	45,300
Pennsylvania (Nutrition)	8	----------	----------	----------	----------	----------
Porto Rico	9	----------	----------	1	18	3,000
Rhode Island	12	----------	----------	10	170	2,800
South Carolina	32	9	6	7	447	5,500
South Dakota	17	21	----------	6	204	15,000
Tennessee	23	2	----------	10	133	12,500
Texas	68	8	----------	15	878	72,103
Utah	36	26	22	3	160	7,000
Vermont	14	11	2	8	377	5,282
Virginia	32	8	1	14	345	12,000
Virgin Islands	3	----------	----------	1	13	520
Washington	42	14	----------	11	564	13,765
West Virginia	37	24	2	12	389	15,000
Wisconsin	98	88	68	18	526	55,783
Wyoming	22	10	2	11	171	8,000
Total	2,415	1,265	347	1,059	2,537	853,732

TABLE 3.—*Revenues and additions to equipment, 1925*

Station	Federal		State	Balances [1] from previous year	Fees	Sales	Miscellaneous	Total	Additions to equipment						
	Hatch fund	Adams fund							Buildings	Library	Apparatus	Farm implements	Livestock	Miscellaneous	Total
Alabama (College)	$15,000.00	$15,000.00	$34,500.00	$16,048.56		$16,329.17		$96,877.73	$1,512.28	$426.92	$765.62	$761.30		$4,726.94	$8,193.06
Alaska [2]							$76,240.00	76,240.00							
Arizona	15,000.00	15,000.00	96,394.84	936.21		3,337.65		130,668.70	2,414.92		921.21	1,491.26	$200.00	3,993.26	9,020.65
Arkansas	15,000.00	15,000.00	74,665.45			17,102.22	1,400.00	123,167.67	38,650.10	949.41	9,471.37	1,079.85	2,201.52	1,677.91	54,030.16
California	15,000.00	15,000.00	507,937.93	34,553.67	$8,699.76	70,664.97	14,004.88	665,861.21	41,604.00	5,592.64	6,745.07	7,997.39	1,626.77	2,957.98	66,523.85
Colorado	15,000.00	15,000.00	122,132.53	33,639.28		24,317.24		210,089.05	9,101.34	872.93	5,001.58	2,292.92	7,328.10	127,616.91	152,213.78
Connecticut (State)	7,500.00	7,500.00	73,870.74	6,169.99	14,500.00		8,882.57	118,423.30	945.48	816.72	2,170.96	1,703.13	1.00	691.61	6,328.90
Connecticut (Storrs)	7,500.00	7,500.00	32,000.00	7,773.34			16,986.58	71,759.92		500.00	3,000.00	100.00		500.00	4,100.00
Delaware	15,000.00	15,000.00	17,500.00	2,301.29		14,407.00		64,208.29		200.00	900.00	500.00			1,600.00
Florida	15,000.00	15,000.00	87,500.00	24,104.90		9,989.91		151,594.81	9,236.61	1,724.54	1,327.71	2,453.21	337.50	6,446.03	21,525.60
Georgia	15,000.00	15,000.00	8,000.00	2,549.26		10,977.19		51,526.45		456.87	27.69		464.36		948.92
Guam [2]							22,860.00	22,860.00							
Hawaii [2]							57,640.00	57,640.00							
Idaho	15,000.00	15,000.00	26,794.59	460.02				57,254.61	76,000.00	250.00	1,000.00	750.00	2,000.00	6,500.00	86,500.00
Illinois	15,000.00	15,000.00	395,444.62	31,723.22		61,704.38		518,872.22	231,295.10					37,468.12	268,763.22
Indiana	15,000.00	15,000.00	226,160.07	114,280.44	145,070.36	100,217.64	22,022.44	637,750.95	38,658.14	1,259.13	3,758.21	11,689.45	19,608.80	2,692.50	77,666.23
Iowa	15,000.00	15,000.00	265,000.00	26,065.03		53,843.75		374,908.78			5,340.37		3,576.00	1,777.07	10,693.44
Kansas	15,000.00	15,000.00	100,400.00	18,645.06		78,165.80		227,210.86	20,386.81	1,672.01	625.23	1,909.33	6,410.70	371.53	31,375.61
Kentucky	15,000.00	15,000.00	113,000.00	31,190.86	99,432.44	42,911.24	5,000.00	321,534.54		1,019.29	846.67	1,960.11	2,699.60	768.62	7,294.29
Louisiana	15,000.00	15,000.00	40,000.00	8,624.26	30,626.05	17,075.95	1,786.18	128,112.44	21,259.32	300.05	1,177.26	3,514.75	1,435.00	501.19	28,187.57
Maine	15,000.00	15,000.00	25,000.00		11,816.40	15,528.96		82,345.36	1,432.24	834.92	168.29	1,690.53	15.00	474.53	4,615.51
Maryland	15,000.00	15,000.00	80,865.38			17,610.56	5,341.99	133,817.93	8,087.30	299.18	1,399.12	3,094.44		216.82	13,096.86
Massachusetts	15,000.00	15,000.00	134,193.17		39,977.05	14,392.81	132.93	218,695.96	4,593.82	1,025.02	1,509.37	2,880.63		842.32	10,851.16
Michigan	15,000.00	15,000.00	284,835.47					314,835.47	6,618.89	667.18	5,776.13	6,512.47	1,259.61	649.21	21,483.49
Minnesota	15,000.00	15,000.00	323,628.91			80,209.99		433,838.90	2,709.75	1,213.19	1,567.87	3,895.12	4,823.61	7,784.86	21,994.40
Mississippi	15,000.00	15,000.00	126,869.76	54,353.00		12,330.58		223,553.34	420.00	312.50	723.89			726.34	2,182.73
Missouri	15,000.00	15,000.00	71,148.88	43,823.00	28,145.46	37,665.89		210,783.23	7,651.98	649.97	3,778.51	4,825.05	8,517.97		25,423.48
Montana	15,000.00	15,000.00	110,727.53	4,096.19		19,285.02	282.74	164,391.48	1,770.00	60.00	840.00	5,700.00	1,290.00	250.00	9,910.00
Nebraska	15,000.00	15,000.00	128,519.10	8,151.17		51,771.82		218,442.09		374.97	3,286.18	3,717.15	14,228.99		21,607.29
Nevada	15,000.00	15,000.00	1,557.20	1,154.99		1,159.52		33,871.71	551.82	220.36	182.75	13.00	781.83	130.55	1,880.31
New Hampshire	15,000.00	15,000.00	7,000.00	3,472.96		2,189.56	14,863.93	57,526.45		550.00	1,444.29	32.22		593.16	2,619.67
New Jersey (State)			129,230.73		49,219.11	29,020.71		207,470.55	44,598.56	752.17	5,862.67	1,110.00	2,381.50	480.00	55,184.90
New Jersey (College)	15,000.00	15,000.00						30,000.00							
New Mexico	15,000.00	15,000.00	7,500.00	21,811.26		8,000.00		67,311.26	468.41	10.81	295.26	1,006.26	1,877.00		3,657.74
New York (State)	1,500.00	1,500.00	254,740.00			8,194.00		265,934.00		1,800.00	3,200.00	2,800.00			7,800.00
New York (Cornell)	13,500.00	13,500.00	240,314.27			24,725.29		292,039.56	6,454.17	1,527.21	2,648.08	2,836.29			13,465.75

North Carolina	15,000.00	15,000.00	155,945.00	2,144.86	----------	43,444.39	844.86	232,379.11	14,661.80	241.29	797.25	2,812.30	1,348.00	2,754.65	22,615.29
North Dakota	15,000.00	15,000.00	----------	178,366.61	----------	75,529.51	11,000.00	294,896.12	2,000.00	253.00	1,981.00	3,400.00	5,686.00	----------	13,320.00
Ohio	15,000.00	15,000.00	405,675.00	248,073.20	----------	50,041.19	2,375.05	736,164.44	106,883.29	391.62	2,017.76	8,974.01	6,769.91	64,701.64	189,738.23
Oklahoma	15,000.00	15,000.00	12,500.00	998.48	----------	14,426.94	----------	57,925.42	952.81	443.77	765.51	2,140.10	1,785.92	----------	6,088.11
Oregon	15,000.00	15,600.00	104,500.00	52,454.98	----------	----------	27,932.75	214,887.73	5,289.66	83.01	220.92	4,581.56	7,111.65	425.55	17,712.35
Pennsylvania	15,000.00	15,000.00	60,408.80	----------	----------	10,906.90	11,236.24	112,551.94	----------	1,007.96	1,666.70	995.07	459.61	944.82	5,074.16
Porto Rico[2]	----------	----------	----------	----------	----------	----------	56,860.00	56,860.00	----------	----------	----------	----------	----------	----------	----------
Rhode Island	15,000.00	15,000.00	4,516.82	161.45	----------	5,469.22	----------	40,147.49	22.00	292.00	91.00	277.00	90.00	6.00	778.00
South Carolina	15,000.00	15,000.00	72,545.79	2,083.33	----------	41,452.01	----------	146,081.16	2,723.01	888.22	927.49	4,887.93	2,440.55	1,683.83	13,551.03
South Dakota	15,000.00	15,000.00	35,420.00	7,643.50	----------	17,325.26	1,778.74	92,167.50	1,223.31	----------	500.00	----------	----------	----------	1,723.31
Tennessee	15,000.00	15,000.00	33,620.61	----------	----------	17,811.27	----------	81,431.88	----------	283.60	340.18	942.74	1,000.00	287.95	2,854.47
Texas	15,000.00	15,000.00	217,000.00	32,935.23	----------	82,772.56	52,903.84	415,611.63	34,304.64	307.20	962.64	16,410.77	5,855.70	2,145.75	59,986.70
Utah	15,000.00	15,000.00	46,891.71	2,225.76	----------	18,061.31	259.85	97,438.63	800.00	50.00	1,000.00	600.00	----------	600.00	3,050.00
Vermont	15,000.00	15,000.00	12,560.78	65.38	----------	1,000.41	----------	43,626.57	1,114.81	224.06	406.96	----------	300.00	----------	2,045.83
Virginia	15,000.00	15,000.00	70,156.25	8,222.56	----------	9,072.10	616.40	118,067.31	1,596.35	553.86	1,994.09	768.88	167.30	----------	5,080.48
Virgin Islands[2]	----------	----------	----------	----------	----------	----------	24,680.00	24,680.00	----------	----------	----------	----------	----------	----------	----------
Washington	15,000.00	15,000.00	101,955.82	----------	----------	49,727.36	----------	181,683.18	3,300.00	1,170.22	3,549.03	3,209.97	1,392.28	----------	12,621.50
West Virginia	15,000.00	15,000.00	85,000.00	8,769.48	----------	38,653.22	----------	162,422.70	15,172.46	232.68	1,249.31	5,782.96	4,106.00	1,572.82	28,116.23
Wisconsin	15,000.00	15,000.00	249,244.13	----------	----------	70,773.61	16,337.20	366,354.94	7,724.00	1,743.66	4,024.88	1,888.00	2,335.82	2,916.00	20,632.36
Wyoming	15,000.00	15,000.00	12,500.00	1,794.93	----------	884.37	----------	45,179.30	8,600.00	875.00	700.00	900.00	5,400.00	3,000.00	19,475.00
Total	720,000.00	720,000.00	5,827,871.88	1,041,867.71	427,486.63	1,390,480.48	454,269.17	10,581,975.87	782,789.18	35,379.14	98,956.08	136,887.15	129,313.60	291,876.47	1,475,201.62

[1] Not including balances from Federal funds.
[2] Supported by direct appropriations to the United States Department of Agriculture.

TABLE 4.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$9,943.36	$1,948.71	$6.07	$285.31	$45.54		$214.76
Arizona	15,000.00	15,000.00						
Arkansas	15,000.00	8,065.00	2,392.62	1,091.34	155.14	160.60	$41.18	194.46
California	15,000.00	15,000.00						
Colorado	15,000.00	14,679.74	27.30		7.40			8.25
Connecticut (State)	7,500.00	7,500.00						
Connecticut (Storrs)	7,500.00	7,500.00						
Delaware	15,000.00	9,770.68	900.53	2,184.56	843.38	4.49	66.32	154.81
Florida	15,000.00	15,000.00						
Georgia	15,000.00	9,292.25	2,940.20	260.11	328.53	74.19	806.70	75.59
Idaho	15,000.00	12,395.38	1,718.82	41.35		7.25	82.76	114.64
Illinois	15,000.00	14,809.37	188.62					
Indiana	15,000.00	14,900.00	100.00					
Iowa	15,000.00	8,415.00	705.46	1,373.20	205.05		53.34	13.26
Kansas	15,000.00	9,700.00	3,965.68	100.00	4.50			158.43
Kentucky	15,000.00	14,873.99						
Louisiana	15,000.00	7,496.95	2,536.28	4.50	55.92	177.70	98.94	
Maine	15,000.00	7,648.08	3,396.41	9.00	232.47	66.77	831.84	61.09
Maryland	15,000.00	14,867.74	125.00		7.26			
Massachusetts	15,000.00	14,750.01						
Michigan	15,000.00	15,000.00						
Minnesota	15,000.00	15,000.00						
Mississippi	15,000.00	9,222.00	3,154.59		1.00	206.69	37.26	
Missouri	15,000.00	6,855.67	3,853.07		210.15	269.52	61.58	103.47
Montana	15,000.00	14,193.33	39.91	464.33		5.58		71.52
Nebraska	15,000.00	15,000.00						
Nevada	15,000.00	10,305.07	1,914.85	291.60	196.57	32.86	46.75	38.95
New Hampshire	15,000.00	10,789.75	413.80	474.80	465.90	307.56	600.00	115.09
New Jersey	15,000.00	10,603.00	894.01	153.00	250.16	16.95	200.40	211.47
New Mexico	15,000.00	7,868.57	3,105.60	1,123.57	135.23	90.24	257.69	89.55
New York (State)	1,500.00	837.50	662.50					
New York (Cornell)	13,500.00	6,178.87	4,620.50	30.10	215.60	63.44	36.40	265.42
North Carolina	15,000.00	13,011.58	1,096.36		250.46	17.78	11.00	
North Dakota	15,000.00	15,000.00						
Ohio	15,000.00	8,093.32	3,350.80		258.50		800.53	
Oklahoma	15,000.00	4,630.00	4,372.34	635.58	122.48	162.08	81.25	159.83
Oregon	15,000.00	10,884.17	2,168.46	481.71	6.13	7.89	8.35	130.84
Pennsylvania	15,000.00	11,800.00	772.38	1,687.75	5.27	103.94	43.00	15.56
Rhode Island	15,000.00	6,206.75	4,604.33	808.47	167.33	236.30	267.86	29.68
South Carolina	15,000.00	8,024.97	1,958.59	524.83	711.83	91.53		27.34
South Dakota	15,000.00	7,899.90	3,175.06	833.43	125.66	24.80		655.07
Tennessee	15,000.00	11,205.00	1,693.01	327,02	251.87	67.32	671.84	26.01
Texas	15,000.00	12,174.88	1,209.97		294.98			
Utah	15,000.00	10,321.00	2,070.80	553.18	78.14	14.27	41.05	58.21
Vermont	15,000.00	6,534.99	2,030.49	2,543.66	230.71	33.15	1,069.57	261.49
Virginia	15,000.00	10,169.92	1,948.47	402.50	318.68	126.43	70.22	101.90
Washington	15,000.00	10,505.20	1,613.60	1,560.46	74.56			50.91
West Virginia	15,000.00	8,787.46	2,707.06		25.55			238.82
Wisconsin	15,000.00	10,000.00	1,848.20	295.79		.64		1,006.22
Wyoming	15,000.00	14,280.00	720.00					
Total	720,000.00	532,990.45	76,944.38	18,261.91	6,521.72	2,415.51	6,285.83	4,652.64

the act of March 2, 1887 (Hatch Act), for the year ended June 30, 1925

Classified expenditures										
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and land
$427.13	$564.05	$373.20	$299.39	$241.76	$127.68	$184.54		$334.10		$4.40
716.95	22.71	660.18	92.14	141.71	257.08	236.24	$181.61	452.98		138.06
9.00			42.11			226.20				
200.21	129.80		268.99	15.10	70.87	4.61		385.65		
307.19	509.68	111.00	16.91	129.70	4.50			143.45		
151.09		112.02	13.00	5.50				328.19		30.00
2.01										
683.37	128.57	3,189.14		103.90		57.40		72.31		
40.55			5.00	452.25	25.04	259.11		289.44		
								126.01		
796.56	741.97	521.85	78.35	1,055.09	55.75		728.00	282.50	$126.00	243.64
101.51	235.20	1,464.95	446.89	72.26	54.71	63.65		279.52		35.65
								249.99		
365.83	241.43	1,515.63		33.53		19.50		149.68		52.86
650.90	23.25	2,105.40	1.78	243.39	11.00	75.28	301.63	67.50	.10	166.31
45.41						21.50		158.42		
274.90	66.00	86.96	220.36	34.60	399.98		200.00	738.71		151.84
121.25	134.04		458.19	236,65	261.00	3.60		618.37		
274.01		360.00	24.29	32.60	78.53	53.15		1,771.07	14.26	63.10
471.39	41.75	668.35		373.60	63.88	1.64	115.05	593.89		
472.84	257.91	23.97	11.00	540.07	128.59			228.22		427.07
285.95		68.95			4.00			253.92		
216.34	22.50	2,202.24						55.77		
815.49		649.93	293.73	593.97	517.85	234.05		1,632.89		98.53
197.37	128.50	193.67	2.00	19.04	18.40			753.47		
105.08	346.52			100.93				7.32		12.25
387.68	965.70	308.32	217.65	268.97	12.35		90.00	237.22	32.17	159.22
350.28	300.00	933.54	697.77	123.24	680.33	21.00		480.11		74.64
371.81		498.25		192.33	575.03	246.16	402.50			
110.07	6.90		257.71	72.47	35.55	10.43		81.35	1.21	182.24
		325.49	24.10	31.40	300.00	50.00	548.86			40.32
368.24		981.22	46.03	1.95	59.88			240.35	15.00	150.68
306.67	129.25	168.53	185.06	159.21	7.07	92.73		498.27	1.35	747.80
553.51	323.47	103.94	155.10	104.99	87.30	101.07	110.00	162.83	20.00	139.67
79.81	9.63		49.00	16.00		156.11		884.72		
1,020.44	76.56		4.50	278.77		259.44		1,589.38		12.02
256.65	59.37			68.68	416.50	939.86		108.09		
11,537.49	5,464.76	17,626.73	3,911.05	5,743.66	4,252.87	3,317.27	2,677.65	14,255.69	210.09	2.930.30

TABLE 5.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures					
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000.00	$11,011.83	$757.95	$163.17	$182.62	$112.73	$97.45
Arizona	15,000.00	12,611.97	277.69	2.70	9.53		231.88
Arkansas	15,000.00	9,200.00	2,818.49	1.07	70.54	75.34	559.83
California	15,000.00	15,000.00					
Colorado	15,000.00	14,373.55	134.70	16.34	.50		25.07
Connecticut (State)	7,500.00	7,500.00					
Connecticut (Storrs)	7,500.00	7,500.00					
Delaware	15,000.00	11,694.17	315.30	17.42	41.95		1,398.14
Florida	15,000.00	15,000,00					
Georgia	15,000.00	11,070.83	522.36	13.40	162.71	445.54	805.30
Idaho	15,000.00	11,718.37	988.91		47.65	72.81	746.56
Illinois	15,000.00	13,026.60	1,973.40				
Indiana	15,000.00	11,915.00	358.65	36.45	22.45		375.50
Iowa	15,000.00	9,395.00	2,298.79	69.17	9.76	38.21	1,346.48
Kansas	15,000.00	10,300.00	3,619.30	3.36	12.09		261.43
Kentucky	15,000.00	14,960.21					
Louisiana	15,000.00	12,606.20	1,008.77	76.16	10.88	74.09	134.37
Maine	15,000.00	15,000.00					
Maryland	15,000.00	13,887.62	214.00	54.34	2.20		487.37
Massachusetts	15,000.00	15,000.00					
Michigan	15,000.00	15,000.00					
Minnesota	15,000.00	15,000.00					
Mississippi	15,000.00	12,399.84	1,839.32		17.62	102.50	
Missouri	15,000.00	3,245.32	3,410.80	131.73	327.76	285.87	1,883.45
Montana	15,000.00	10,470.96	2,247.67	65.79	7.48	2.00	419.57
Nebraska	15,000.00	15,000.00					
Nevada	15,000.00	7,900.00	3,249.25	14.20	43.85	173.46	227.52
New Hampshire	15,000.00	11,630.00	899.08	38.62	121.81		341.58
New Jersey	15,000.00	12,885.00	87.18	13.53	3.92	756.27	711.85
New Mexico	15,000.00	9,334.16	3,637.76	60.97	155.58	446.43	150.70
New York (State)	1,500.00	1,500.00					
New York (Cornell)	13,500.00	10,682.24	1,667.68	34.16	22.75		875.15
North Carolina	15,000.00	12,366.01	948.04	61.36	29.55	17.38	581.59
North Dakota	15,000.00	15,000.00					
Ohio	15,000,00	11,500.00	2,373.06	6.95			
Oklahoma	15,000.00	10,180.00	1,860.18	26.04	11.15		489.45
Oregon	15,000.00	13,650.01	647.36	18.11	46.46	56.97	467.03
Pennsylvania	15,000.00	12,933.60	636.95	6.69	34.45	7.18	445.15
Rhode Island	15,000,00	9,591.78	2,311.62	30.84	17.55	670.75	153.96
South Carolina	15,000.00	10,691.05	1,679.23	263.82	38.39	225.00	229.53
South Dakota	15,000.00	7,841.58	5,462.62	45.71	14.57		500.64
Tennessee	15,000.00	13,680.00	40.30	16.15	70.83	128.37	570.46
Texas	15,000.00	13,344.84	827.31	58.08	16.10		406.26
Utah	15,000.00	10,299.96	2,950.90	33.68	56.73		646.08
Vermont	15,000.00	9,716.67	2,810.05	44.16	21.83	229.51	207.14
Virginia	15,000.00	11,236.99	2,764.73	2.80	86.66		92.02
Washington	15,000.00	11,370.91	1,761.80	10.00			412.22
West Virginia	15,000.00	12,176.61	429.12	90.60	1.25		133.58
Wisconsin	15,000.00	9,720.00	3,662,63		12.89		276.29
Wyoming	15,000.00	13,979.75	1,020.25				
Total	720,000.00	577,098.63	64,513.20	1,527.57	1,732.06	3,920.41	16,690.60

the act of March 16, 1906 (Adams Act), for the year ended June 30, 1925

Classified expenditures										
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and land
$619.54	$24.22	$751.55	$127.53	$519.54	$50.79	$581.08	--------	--------	--------	--------
280.98	--------	--------	--------	6.15	--------	921.91	--------	$657.19	--------	--------
436.00	7.25	378.38	--------	4.13	--------	1,061.68	$43.50	240.63	--------	$103.16
12.66	--------	10.40	19.70	.80	--------	284.83	--------	121.45	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
296.00	--------	--------	61.34	--------	--------	873.78	--------	301.90	--------	--------
63.00	66.00	1,282.15	67.12	71.12	--------	25.69	234.36	170.42	--------	--------
54.36	122.25	114.70	--------	1.00	--------	82.41	--------	1,050.98	--------	--------
288.73	--------	--------	18.14	26.05	40.72	915.26	773.00	190.05	--------	40.00
483.51	--------	684.14	--------	11.19	--------	408.93	--------	254.82	--------	--------
47.89	--------	417.42	3.38	10.43	16.00	21.04	22.50	103.18	--------	161.98
								39.79		
132.64	--------	64.35	48.49	7.10	6.00	679,06	30.00	106.89	--------	15.00
28.38	--------	--------	1.00	28.00	24.70	252.71	--------	13.05	--------	6.63
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
99.24	7.00	--------	35.35	39.35	--------	341.95	--------	117.83	--------	--------
458.44	12.52	2,850.23	5.00	962.31	139.13	508.19	122.30	106.72	$70.00	480.23
102.45	--------	--------	--------	153.83	10.35	603.16	--------	916.74	--------	--------
40.63	--------	1,502.90	3.15	10.00	--------	703.97	581.83	549.24	--------	--------
109.89	--------	384.86	--------	414.76	67.70	254.38	--------	42.38	--------	694.94
110.15	--------	--------	--------	4.95	2.25	372.36	--------	30.34	3.34	18.86
126.91	124.23	529.74	--------	191.45	81.77	56.24	63.00	10.06	--------	31.00
108.71	--------	--------	--------	7.32	--------	76.99	--------	--------	--------	25.00
76.79	193.04	--------	--------	--------	--------	450.03	--------	276.21	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
--------	--------	83.67	--------	--------	--------	1,036.32	--------	--------	--------	--------
473.62	5.65	806.26	99.95	151.09	137.75	498.37	172.05	26.74	--------	61.70
37.62	--------	18.10	3.00	55.34	--------	--------	--------	--------	--------	--------
11.50	136.00	--------	116.40	31.04	3.00	586.97	--------	48.79	2.28	--------
123.76	--------	1,697.53	38.75	115.70	1.70	81.24	17.50	--------	--------	147.32
184.97	300.00	--------	102.67	440.59	436.50	312.35	--------	39.40	--------	56.50
272.51	26.20	60.45	--------	69.84	340.75	217.91	80.00	55.89	--------	11.33
44.61	--------	--------	39.55	13.70	19.16	116.18	--------	136.39	2.38	121.92
47.57	--------	--------	--------	142.38	--------	5.65	100.00	--------	--------	51.81
203.05	--------	--------	8.50	58.53	7.75	394.81	--------	262.30	--------	77.71
292.82	24.10	567.31	26.25	63.88	44.62	171.48	300.00	158.88	13.79	307.51
71.62	--------	303.05	--------	8.60	21.15	407.88	--------	--------	--------	4.50
431.09	--------	--------	12.29	45.00	107.33	410.50	--------	438.86	--------	--------
147.30	--------	193.29	--------	102.31	--------	1,530.71	--------	195.23	--------	--------
101.03	--------	951.15	--------	35.48	--------	236.03	--------	4.50	--------	--------
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
6,419.97	1,048.46	13,651.63	837.56	3,802.96	1,559.12	15.482.05	2,540.04	6,666.85	91.79	2,417.10

TABLE 6.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, and March 16, 1906*

State or Territory	Hatch Act		Adams Act	
	1888-1924	1925	1906-1924	1925
Alabama	$553,956.42	$15,000.00	$251,619.89	$15,000.00
Arizona	519,803.10	15,000.00	254,955.61	15,000.00
Arkansas	553,139.12	15,000.00	254,900.00	15,000.00
California	555,000.00	15,000.00	254,926.84	15,000.00
Colorado	554,718.82	15,000.00	253,638.93	15,000.00
Connecticut	555,000.00	15,000.00	255,000.00	15,000.00
Dakota Territory	56,250.00	----------	----------	----------
Delaware	553,382.87	15,000.00	250,475.12	15,000.00
Florida	554,966.04	15,000.00	254,996.06	15,000.00
Georgia	550,593.43	15,000.00	242,092.87	15,000.00
Idaho	479,324.13	15,000.00	250,842.22	15,000.00
Illinois	554,564.95	15,000.00	254,851.62	15,000.00
Indiana	554,901.19	15,000.00	255,000.00	15,000.00
Iowa	555,000.00	15,000.00	255,000.00	15,000.00
Kansas	504,995.00	15,000.00	255,000.00	15,000.00
Kentucky	554,996.57	15,000.00	255,000.00	15,000.00
Louisiana	555,000.00	15,000.00	255,000.00	15,000.00
Maine	554,999.62	15,000.00	255,000.00	15,000.00
Maryland	554,967.40	15,000.00	254,236.48	15,000.00
Massachusetts	554,617.70	15,000.00	255,000.00	15,000.00
Michigan	554,676.10	15,000.00	251,341.20	15,000.00
Minnesota	554,917.78	15,000.00	254,345.00	15,000.00
Mississippi	555,000.00	15,000.00	255,000.00	15,000.00
Missouri	550,097.24	15,000.00	254,999.90	15,000.00
Montana	465,000.00	15,000.00	252,417.04	15,000.00
Nebraska	554,932.16	15,000.00	255,000.00	15,000.00
Nevada	554,214.32	15,000.00	253,180.28	15,000.00
New Hampshire	555,000.00	15,000.00	255,000.00	15,000.00
New Jersey	554,949.97	15,000.00	254,392.06	15,000.00
New Mexico	519,509.05	15,000.00	255,000.00	15,000.00
New York	554,757.18	15,000.00	254,463.01	15,000.00
North Carolina	555,000.00	15,000.00	240,000.00	15,000.00
North Dakota	496,502.26	15,000.00	254,638.85	15,000.00
Ohio	555,000.00	15,000.00	253,514.02	15,000.00
Oklahoma	479,002.16	15,000.00	234,535.19	15,000.00
Oregon	540,156.64	15,000.00	250,000.00	15,000.00
Pennsylvania	554,967.43	15,000.00	254,995.41	15,000.00
Rhode Island	555,000.00	15,000.00	252,464.20	15,000.00
South Carolina	554,542.15	15,000.00	253,460.12	15,000.00
South Dakota	498,250.00	15,000.00	250,000.00	15,000.00
Tennessee	555,000.00	15,000.00	255,000.00	15,000.00
Texas	555,000.00	15,000.00	252,592.26	15,000.00
Utah	420,000.00	15,000.00	254,821.94	15,000.00
Vermont	555,000.00	15,000.00	255,000.00	15,000.00
Virginia	552,824.12	15,000.00	254,949.01	15,000.00
Washington	492,102.65	15,000.00	251,080.11	15,000.00
West Virginia	554,968.71	15,000.00	252,859.12	15,000.00
Wisconsin	555,000.00	15,000.00	255,000.00	15,000.00
Wyoming	540,000.00	15,500.00	255,000.00	15,000.00
Total	26,021,546.28	720,000.00	12,142,584.36	720,000.00

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UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1925

PREPARED BY THE

OFFICE OF EXPERIMENT STATIONS

WASHINGTON : GOVERNMENT PRINTING OFFICE : 1926

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RELATIONS WITH THE STATE EXPERIMENT STATIONS

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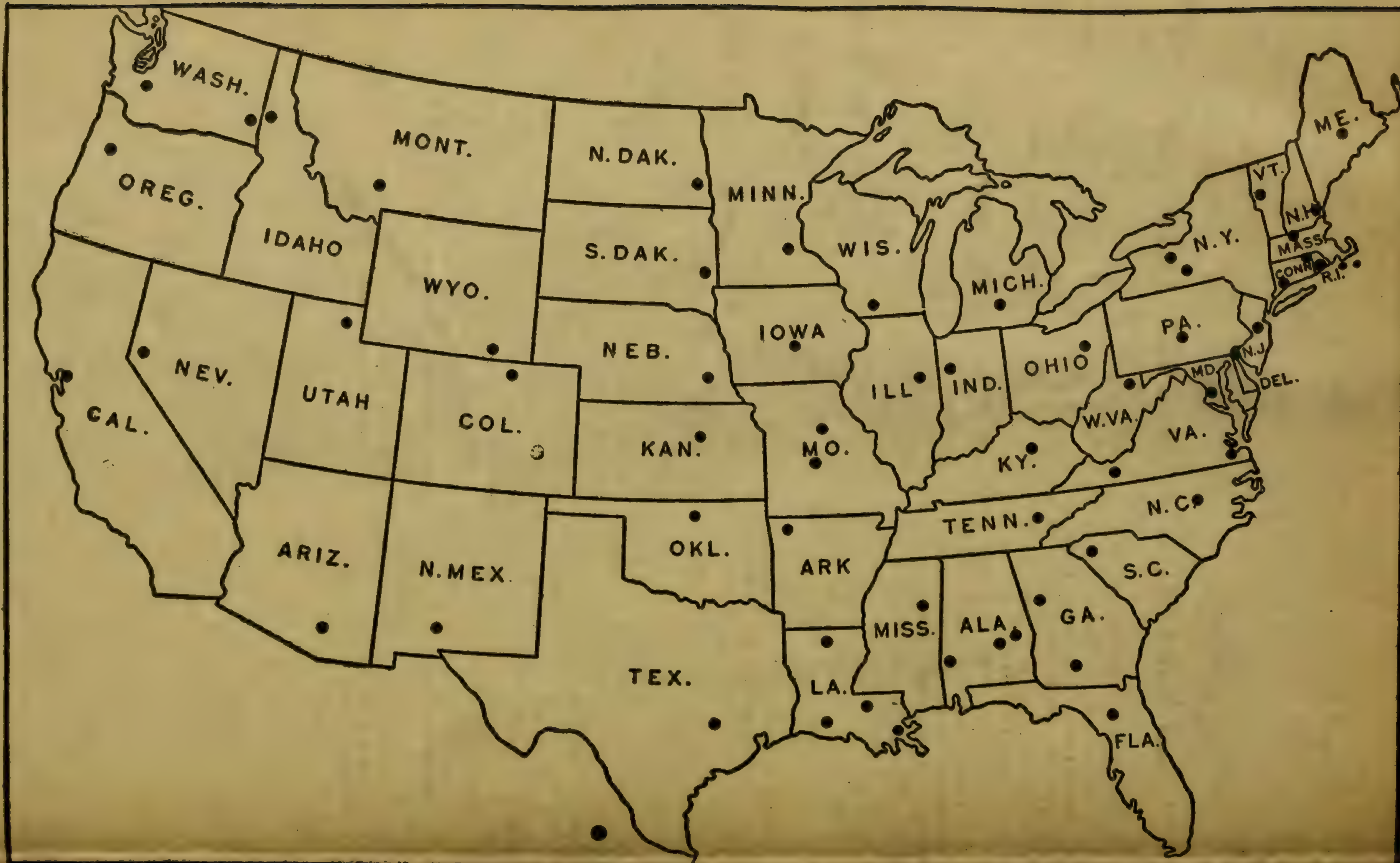
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